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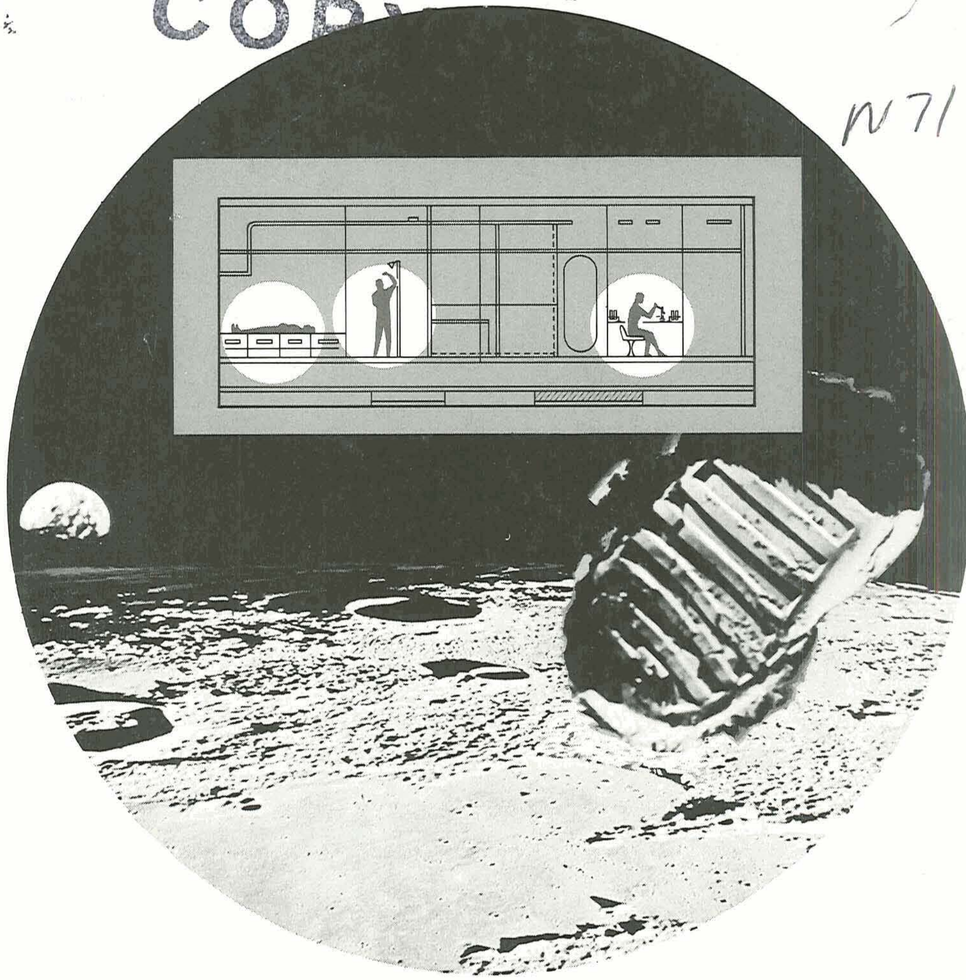

ORBITING LUNAR STATION (OLS)

PHASE A FEASIBILITY AND DEFINITION STUDY

VOLUME III

OLS PERFORMANCE REQUIREMENTS

FINAL REPORT

Space Division
North American Rockwell

APRIL 1971
Prepared by Advanced Program Engineering

12214 Lakewood Boulevard, Downey, California 90241

SD 71-207
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ORBITING LUNAR STATION PHASE A FEASIBILITY AND DEFINITION STUDY

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APRIL 1971

Approved by

L. R. Hogan

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Program Manager
Orbiting Lunar Station Study

Space Division
North American Rockwell

FOREWORD

This report contains the results of North American Rockwell's analyses conducted under the Orbiting Lunar Station Feasibility and Definition Study (Phase A), Contract NAS9-10924, in accordance with line item 5 of the Data Requirements List (DRL5).

This report is compiled in six volumes for ease of presentation, handling and readability of the data in the report. In general, each volume is a compilation of the data generated in a specific phase of the study.

This is Volume III of the report and contains Orbiting Lunar Station (OLS) overall design criteria, mission requirements, and subsystem requirements. In addition, requirements are presented for experiment provisions, crew and habitability provisions, and docking provisions.

Subsystem and provisions requirements are categorized as functional or performance requirements. Rationales for these requirements are presented where the reasons for these requirements are not immediately obvious. Differences between representative and derivative OLS requirements are indicated where they exist.

The documents comprising the study report are:

Volume I	OLS Objectives
Volume II	Mission Operations and Payloads Analysis
Volume III	OLS Performance Requirements
Volume IV	OLS Configuration and Subsystem Synthesis
Volume V	OLS Configuration Definition
Volume VI	Comparison of OLS Configurations

ACKNOWLEDGEMENTS

The following persons have participated in the definition of OLS performance requirements, and have contributed to the preparation of this report:

L. R. Hogan	Program Manager
J. J. Armstead	Project Engineer, OLS Configuration/ Systems Analysis
W. L. Steinwachs	Project Engineer, OLS Operations Analysis
F. H. Daurio	Systems Analysis
G. S. Canetti	Safety
M. M. Sanger	Crew Systems
G. G. Freeman	Subsystem Requirements
E. F. Kraly	Scientific Support Requirements
R. W. Westrup	Structures
M. Feiner	Environmental Protection
R. D. Trust	Environmental Control/Life Support
T. H. Moore	Communications
C. R. Gerber	Information Management
M. F. Madden	Guidance and Control
R. W. Benjamin	Docking
J. Ambrose	Electrical Power
J. O. Bartlett	Propulsion

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1.0 INTRODUCTION AND SUMMARY

In the functional analysis task, the Orbiting Lunar Station (OLS) scientific and operational objectives were analyzed, and the supporting OLS functions were identified. Systems analyses were then performed to determine the OLS preliminary design criteria, including subsystems functional and performance requirements supporting these identified OLS objectives and functions. These requirements, which include OLS overall design criteria, mission operational requirements, and subsystem and provisions requirements, are presented in this volume. As the objectives, functions, and operational mode of the OLS are similar in many respects to those of the Earth Orbit Space Station (EOSS), the EOSS Performance Specification, SD 70-510-1, dated July 1970, was employed as a baseline model and checklist in the determination and documentation of the OLS system requirements. The EOSS design criteria, operational requirements, and subsystems requirements were reviewed by the OLS personnel and adopted, rejected, or modified into applicable Phase A OLS preliminary design requirements. These requirements were then supplemented with the addition of requirements unique to the lunar orbit situation and/or required to support OLS objectives. The results of these efforts are presented in the following sections as OLS preliminary design requirements.

The volume is divided into six sections, summaries for which are given below. These six sections include:

- 2.0 Overall Design Criteria
- 3.0 Mission Requirements
- 4.0 Experiment Provisions Requirements
- 5.0 Crew and Habitability Provisions Requirements
- 6.0 Docking Provisions Requirements
- 7.0 Subsystem Requirements

1.1 OVERALL DESIGN CRITERIA

Overall OLS design criteria has been formulated based primarily on EOSS criteria in the special emphasis areas of long-life system assurance, onboard checkout and fault isolation, test philosophies, and material and flammability control. General OLS operability criteria has been established in the areas of reliability, maintainability, useful life, environments, human performance, and transportability. System safety criteria are also established. This material is based primarily on material developed during NR's Phase B EOSS study with modifications, particularly in the environments area, for the differing lunar environment.

1.2 MISSION REQUIREMENTS

Design-to and operate-to OLS conditions are defined. Operate-to-conditions include low-altitude earth orbits of 200- to 400-n mi altitudes with inclinations from 28.5 degrees to 55 degrees during earth orbit checkout operations, and 60-n mi circular lunar orbits of any inclination. The design-to lunar orbit is 60-n mi polar. The OLS baseline mission is described from countdown to OLS mission termination.

1.3 EXPERIMENT PROVISIONS REQUIREMENTS

The functional and performance requirements, operability requirements, and experiment provisions-to-subsystem interface requirements are defined together with supporting rationale. Key requirements are as follows:

Floor area required - 240 square feet

Airlocks required - one, with provision for handling of subsatellites

Average experiment provisions power requirement - 4 kw

Experiment provisions crew support requirement - 5 men working 10-hour days

Daily average digital data rate - 1×10^5 bps

Data processing capability - 1×10^{10} bpd

Ephemeris accuracy requirements -

Altitude	± 330 feet, 1 sigma
In-track	± 850 feet, 1 sigma
Cross-track	± 490 feet, 1 sigma
Velocity	± 0.4% (25 fps), rms

1.4 CREW AND HABITABILITY PROVISIONS REQUIREMENTS

The functional and performance requirements, operability requirements, and crew and habitability provisions-to-subsystem interface requirements are defined together with support rationale. The key requirement is:

The OLS shall provide the capability to support a nominal crew complement of eight crewmen with a maximum capability to support 20 crewmen for 55 days during periods of crew rotation/overlap, logistics resupply, or lunar surface base rescue.

1.5 DOCKING PROVISIONS REQUIREMENTS

The functional and performance requirements, operability requirements, and docking provisions-to-subsystem interface requirements are defined together with supporting rationale. Key requirements are as follows.

1. The docking function shall be capable of precontact and contact alignment for docking elements with the following velocity and alignment:

    a. Axial velocity (closing velocity) up to 0.5 fps

    b. Radial velocity (cross-axis translation rate) up to 0.3 fps

    c. Angular velocity (change of rate in attitude) up to 0.5 degree per second

    d. Radial alignment (centerline miss distance) up to $\pm$ 5 inches

    e. Angular alignment (pitch and yaw misalignment) up to $\pm$ 4 degrees

    f. Rotational alignment (roll misalignment) shall be limited to $\pm$ 4 degrees

2. The representative OLS requires six docking ports of which the two axial core module ports are active.

3. The derivative OLS requires a minimum of 13 docking ports (4 operational plus 9 assembly) on the two core module of which the two axial ports on core module 1B are active.

4. Both OLS configurations require 4 active/active docking adapters.

1.6 OLS SUBSYSTEM REQUIREMENTS

Functional and performance requirements, operability requirements, and subsystem-to-subsystem interface requirements of each OLS subsystem are defined together with supporting rationale. Key requirements in each OLS subsystem area are as follows.

1. Structures Subsystem (SS).

    Primary structure factors of safety for unmanned launch:

    Ultimate = 1.50
    Yield = 1.20

Primary structure factors of safety for manned operations in lunar orbit:

Ultimate = 2.00
Yield = 1.50

Short duration or transient loadings:

Ultimate = 1.75
Yield = 1.30

The -X axis docking port of both the representative and derivative OLS configurations shall have sufficient strength to withstand the 38K-pound thrust loads of a space tug during orbital maneuvers and attitude control.

2. Environmental Control and Life Support Subsystem (ECLSS). The OLS atmosphere storage and supply shall consist of a mixture of oxygen and nitrogen. The cabin atmosphere oxygen shall be maintained at a partial pressure of 3.1 psia minimum to 3.5 psia maximum. Nitrogen shall be used as the atmosphere diluent. The total atmospheric pressure shall be maintained at a nominal 14.7 psia with deviations to a minimum of 10.0 psia allowable.

3. Electrical Power Subsystem (EPS). Electrical power requirements during the various phases of OLS operations differ significantly between the representative and derivative OLS configurations as a result of operational sensitivity to the modular concept. Both OLS configurations require an average of 20 kw during normal manned lunar orbit operations.

4. Information Subsystem (ISS). External communications shall provide communication links between the OLS and earth orbital and ground elements and between the OLS and other lunar program elements. Continuous voice communication with elements not in line-of-sight is not required. Use of data relay satellites will provide continuous capability. Capability to communicate with and obtain biomedical and portable life support subsystem data from EVA crewmen shall be provided.

5. Guidance and Control Subsystem (G&C). The OLS G&C shall be capable of maintaining station axes fixed with respect to inertial coordinates in X-POP inertial flight mode within $\pm$ 0.25 degree.

The station also shall be capable of operating in a fine pointing mode for periods up to 30 minutes, with the vertical field within $\pm$ 0.1 degree.

The OLS G&C shall be capable of limiting angular rates about the vehicle axes to 0.05 degree per second continuously and to 0.01 degree per second in the fine pointing mode.

6. Reaction Control Subsystem (RCS). The RCS shall be capable of providing forces for orbit maintenance. The RCS shall be capable of providing the control torques and forces required for OLS maneuvers. The RCS shall size cryogenic gases and subsatellite propellant storage for 180 days of normal operations.

7. Environmental Protection Subsystem (ENPS). The ENPS shall provide thermal protection to the OLS to limit the minimum interior wall and equipment surface temperatures to 57 F. The ENPS shall provide micrometeoroid protection to a probability of 0.9 of no micrometeoroid penetration of crew or systems compartments for 10 years. The ENPS shall provide the required shielding of a solar storm shelter to protect the crew from the radiation of solar flare events.

2.0 OVERALL DESIGN CRITERIA

This section presents the overall design criteria of the Orbiting Lunar Station. The major categories included in the discussion are: design criteria, operability, system safety, and general guidelines and constraints.

2.1 DESIGN CRITERIA

2.1.1 Long-Life System Assurance

Ground Rules

1. Non time-critical functions ultimately critical to crew survival require standby redundancy as a minimum.

2. Subsystem or component failure shall not propagate sequentially; equipment shall be designed to fail safe.

3. Redundant paths, such as fluid lines, electrical wiring, connectors, and explosive trains, shall be located to ensure that an event that damages one line is not likely to damage the other.

4. Replaceable units will be designed to permit direct visual and physical access by the crew with connectors and couplings for ease of removal/replacement. Precision elements will be provided with suitable guides and locking devices to aid in replacement.

Criteria

1. Man-machine interface compatibility should be considered to eliminate or reduce human error potentials.

2. Special tools for repairs or replacement shall be kept to a minimum.

3. Hardware design shall consider state-of-the-art for material selection such that wear of this material will not degrade performance beyond acceptable tolerances for subsystem or structural performance.

2.1.2 Onboard Checkout and Fault Isolation

Ground Rules

1. Ground Participation in OnBoard Checkout (OBCO). The onboard checkout function should be accomplished by autonomous capability onboard the OLS with ground backup on an as-required basis. Confidence in all hardware, software, and crew operations will be obtained during the initial phases of the program when resources will be available for initial launches and program evaluation.

2. Automation of Onboard Checkout Function as It Effects Crew Participation. A high degree of automation shall be provided. Complete automation of the monitoring and alarm, self-test, and fault isolation/detection necessary for crew safety are required. Substantial automation should be provided on a cost effective basis for the remaining subfunctions (i.e., fault prediction, detection, isolation and certification for noncritical safety items, calibration, and record keeping).

3. Integration of Checkout Function Into Information Subsystem (ISS). The checkout function shall be integrated into the ISS.

4. Location of ISS Data Acquisition Equipment Relative to Space Station Subsystems. The acquisition and distribution subassemblies (remote acquisition and control units, RACU) should be located as close as possible to the source transducer. The RACU should be built into the in-flight replacement unit (IFRU) where the number of measurements and complexity of the IFRU justify this approach.

Criteria

1. The OBCO function shall monitor the status of the in-flight replacement units within the subsystem of the OLS to the degree necessary to detect impending or actual malfunctions.

2. The OBCO function shall be able to trace (i.e., isolate) the cause of detected malfunctions to the failed IFRU causing the malfunction.

3. For those malfunctions and failures that may result in time-critical, hazardous or emergency situations for the crew, the OBCO function shall be capable of automatically (1) detecting the malfunction, (2) tracing the failure to the IFRU, (3) switching the necessary subsystem to an alternative safe operational mode if available, (4) warning the crew of the existence of an emergency situation if it still exists, and (5) presenting the crew with the necessary information concerning the malfunction, the failure, the action taken by the OBCO function, and the corrective action required by the crew.

4. For those malfunctions and failures for which the OBCO function has determined (by tracing failures in its automatic mode of operation) that no time-critical, hazardous or emergency situations exist, the OBCO function shall either automatically or by using man-in-loop (1) detect the malfunction, (2) trace the failure to the IFRU, (3) caution the crew that an impending or actual malfunction has occurred, and (4) present the crew with the necessary information describing the malfunction and the further action required by the crew to trace, correct, or otherwise overcome the malfunction.

5. Tracing of failures by the OBCO function shall cease at the largest subassembly consistent with (1) determination of failed subassemblies which can be replaced or repaired by in-flight maintenance, (2) determination that all failed subassemblies or IFRU's causing the malfunction have been identified, and (3) determination that no time-critical or hazardous situation may be identified by tracing to a lower level.

6. The OBCO function shall be capable of detecting malfunctions and failures arising within the ISS performing the OBCO function. All sensor or other failures in the IFRU's shall fail safe (i.e., will not indicate a malfunction in other IFRU's).

7. The information subsystem (ISS) performing OBCO shall be maintainable. The ISS shall be redundant where maintenance is not possible or where a failure in the OBCO function may leave undetected a time-critical, hazardous or emergency situation.

8. The OBCO function shall be capable of checking out the operation of a subsystem following maintenance. The checkout shall be capable of being performed without inducing failures leading to hazardous situations if the maintenance action has been incorrectly performed. In the event of the subsystem malfunctioning, the error in the maintenance action shall be traced and the information presented to the crew.

2.1.3 Test Philosophies

All development requirements resulting from new designs will be satisfied by either analysis, development tests, or a combination of both. In those cases requiring resolution by test, the following criteria will apply.

Development Test Criteria

1. The establishment of a data bank and the determination and verification of checkout and operational procedures will be a requirement of the subsystem development program.

   Rationale - During development testing, the parameters that most clearly indicate the status of the subsystem and/or component being tested will be established. These data will be incorporated into the data bank for use in checkout procedures.

2. Maintenance concepts and procedures will be developed on the subsystem development program and verified on the mission support vehicle.

   Rationale - The mission support vehicle configuration will be maintained both physically and functionally; therefore, maintenance concepts and procedures as appropriate with one g can be verified.

3. Structural testing will verify a satisfactory design margin for operational limits.

   Rationale - To reuse major structural test articles in subsequent test operations, destructive testing of major structural test articles will be avoided. Tests performed on major structural test articles will not exceed ultimate.

4. All primary structure and structural interfaces between program elements will be statically and dynamically verified by test, analysis, or a combination thereof.

   Rationale - Adequate tooling and/or fit-check fixtures will be used to demonstrate physical mating of all program elements prior to initial launch to ensure operational compatibility with the orbiting station. These same tools and/or fixtures will be used to verify the compatibility of subsequently launched elements with existing elements.

5. The initial onboard checkout capability and its software will be verified using the compatibility mockup (CMU). Subsequent capabilities and their hardware will be verified on the mission support vehicle.

   Rationale - To use the onboard checkout system as a checkout tool, the subsystem software must be verified prior to its operational use. The MSC or CMU will be a part of this function.

6. Mission-life tests will be based upon resupply considerations and multiples thereof rather than total life expectancy of 10 years. Another possibility is scheduled maintenance periods or multiples of these periods.

   Rationale - To support program guidelines of a 1983 launch, it is impossible to use classic life tests (i.e., two times mission life plus one ground cycle. These data are logical basis for mission-life testing.

7. All subsystem development testing will include a teardown and inspection phase. The degree of teardown and inspection will be individually defined for each subsystem.

   Rationale - Incipient failures may not be identified during the actual test conduct; therefore, a subsequent inspection of the test hardware is justified to identify those areas where high wear or other potential failure modes may exist. These data may be applied to subsequent malfunction investigations.

Qualification Test Criteria

1. The requirement for a qualification program at the component or subassembly level will be limited to selected components for which realistic acceptance environment cannot be established without impairing subsequent performance.

   Rationale - Component-subassembly performance specifications used for flight hardware acceptance will include realistic operational environment characteristics that must be met.

2. The qualification tests at the subsystem level will be for the purpose of verifying interfaces and interactions with other subsystems and with the Information Management System/Onboard Checkout at the functional limits and in normal operation including alternate and redundant modes. Environmental testing will not be required.

   Rationale - Because there is no distinction between qualification and flight hardware, the components and subassemblies that comprise a subsystem will have been acceptance-tested as flight hardware and exposed to operational environments. The interfaces between components-subassemblies will be functionally verified in the subsystem qualification tests but will rely upon good design and physical inspection for environmental suitability.

Acceptance Test Control

Components. Acceptance tests at the component-subassembly (defined as the level prior to installation in a complete subsystem or vehicle) level will include flight level environments plus a margin to ensure that the accepted item will perform its required function in the operational environment at its anticipated extremes.

Rationale - If a realistic assessment of the operational environment and adequate performance margins are incorporated into the requirements of the acceptance specification at the component-subassembly level, the need for formal qualification testing at this level can be eliminated.

Subsystems.

1. Acceptance testing at the subsystem level (installed in program element) will include a demonstration of alternate/redundant modes of operation, together with the malfunction switching logic, by exercising subroutines inherent to the onboard checkout capability. Wherever possible, alternate-redundant path checkout capability, via malfunction simulation, will be an inherent subsystem checkout feature accomplished without disturbing the flight configuration.

   Rationale - Acceptance of a subsystem end-item by the prime contractor is not complete until alternate-redundant modes of operation have been successfully demonstrated. This same philosophy will apply at the system level primarily to verify all functional interfaces and to verify that the onboard checkout capability will adequately status all modes of operation by means of appropriate subroutines.

2. Each subsystem test program will include subsystem acceptance tests prior to installation. Subsystem performance will be to the same operational ranges expected in flight. Dynamic interfaces with other subsystems will be simulated with bench level equipment.

   Rationale - These tests, performed with flight hardware, will minimize the total test effort on the flight vehicle necessary to demonstrate its flight readiness.

3. Electromagnetic compatibility will be established at the design level and verified in the normal test and checkout sequence.

   Rationale - Integrated tests in the development and acceptance cycle will verify that no electromagnetic interference problems exist.

4. Vacuum testing of a complete program element (OLS core module, cargo module, etc.) will not be required.

   Rationale - Development-acceptance vacuum tests at the submodular or modular assembly level are now sufficient with the current state-of-the-art. The entire structure will undergo pneumostat tests followed by periodic pressure checks.

5. Acceptance of subsystems or IFRU's not operating during launch will include functional tests after being subjected to the simulated launch environment (must survive launch environment as packaged and then function properly).

   Rationale - In the establishment of acceptance criteria, consideration will be given to operating versus passive modes. An example is the solar arrays - launch environment will be applied in the stowed configuration, not in the deployed configuration.

6. The onboard checkout capability will be used as a basis of acceptance testing for the OLS end item.

   Rationale - Recognizing that the IMS is designed for orbital checkout, the onboard checkout capability will be adequate for acceptance testing at the IFRU level during factory-prelaunch testing. This will result in a significant reduction in the ground test time and Ground Support Equipment (GSE) requirements.

Operational Test Criteria

1. There will be no development flight(s) of a complete OLS. Any launch of the station will result in OLS operations.

   Rationale - If a completely configured station is successfully launched, there is no reason not to make it into an operational facility. Partially configured vehicles will be launched to verify design adequacy if required.

2. Each subsystem initially installed in the OLS or replaced in flight will have the capability of having subsystem functions and associated interfaces verified prior to going on-line.

   Rationale - The operation of the OLS could be degraded by an IFRU that has lost some functional capability because of (1) the logistics flight environments or (2) long-range storage (either on the ground or aboard the OLS). To preclude the possibility of disrupting OLS operations, the IFRU must be verified to be in good operational condition before going on-line.

3. All new and/or modified subsystems supplied via the resupply system will have sufficient OBCO test programs (subroutines) developed, qualified, and supplied with the new equipment.

   Rationale - Design changes may result in OBCO test program (subroutine) changes that cannot be developed aboard an orbiting lunar station. The proper place for such development is a suitable computer program plus mission support vehicle activity.

4. Electrical power will be applied continuously from factory checkout (subsystems installed in core module) through orbital life. During transport from the factory to the launch site, subsystems will have the capability of remaining activated.

   Rationale - Transporting upright by barge for 30 days, the onboard checkout system will demonstrate continuous subsystems statusing and maintenance-repair concepts during ground operations.

5. The onboard checkout capability will be used as a basis of acceptance testing for the OLS end items.

   Rationale - Recognizing that the IMS is designed for orbital checkout, the onboard checkout capability will be adequate for acceptance testing at the IFRU level during factory/prelaunch testing. This will result in a significant reduction in ground test time and GSE requirements.

6. Onboard calibration of subsystems and test equipment for orbital operations will be used for factory/prelaunch ground operations to maintain the OLS.

   Rationale - IMS checkout-maintenance capabilities for orbital work will be further utilized during ground operations to reduce test times, repair times, and the need for GSE.

7. Interfaces of the OLS with the corresponding facilities and launch vehicles (INT-21, S-V) will be standard and centrally located wherever possible.

   Rationale - Minimum modifications between launch vehicles and the various modules and payloads will be required to support 1983 launch rates. Minimum facility turnaround times will also be required to support 1983 budgets and rates.

8. It is desirable that all electrical-mechanical interfaces for unmanned payloads go through a single umbilical. At the launch complex, all personnel access will be across the umbilical swing arm.

Rationale - No mobile support structure would be required for unmanned payloads.

9. All physical and functional interfaces between OLS elements will be verified by test, analysis, or a combination thereof.

   Rationale - The mission support vehicle will be used to demonstrate physical and functional mating of all the OLS elements prior to launch.

2.1.4 Material and Flammability Control

To control fire and toxicity hazards resulting from the use of organic materials, to an acceptable level, the criteria in the following paragraphs shall be used in considering material selections and configurations in the OLS study. These criteria also shall be imposed in any discussions with equipment or subsystem suppliers or subcontractors.

Material Selection - Pressurized Areas

1. Flammability, General. Materials proposed for extensive use shall be self-extinguishing in all atmospheric conditions allowed by Table 1 of NASA MSC-00141, Guidelines and Constraints Document. To utilize existing flammability data, materials shall be selected from those classified as self-extinguishing in a 100-percent atmosphere, 5-psia pressure, minimum, as tested per Reference 1 or 2. Flammability ratings of most candidate non-metallic materials are listed in References 3 and 4. If the function, cost, or producibility would be critically affected by these restrictions, materials may be considered which are classified as self-extinguishing in air at earth atmospheric pressure per ASTM D-568, or nonburning in air per ASTM D-635, or self-extinguishing in air at 14.7 psi (Reference 4).

2. Flammability, Minor Exposed Areas. The requirements for materials used in small localized areas may be relaxed to permit a selection from those classified as slow burning (e.g., rate of flame propagation to be less than 0.3 inch per minute when tested per Reference 1).

3. Outgassing and Odor. Materials selected shall be restricted in the amount of organic material, CO, and odor-producing products emitted as tested and limited per Reference 2. Ratings of many candidate materials are shown in References 3 and 4. Judicious use of small quantities of materials failing to meet these requirements may be permitted.

4. Smoke. Materials selected shall have a low level of smoke emission when subjected to heat or ignition sources. A maximum smoke accumulation rating (DM) of 16 shall be used as a material selection criterion. Test methods and ratings of various interior furnishing materials are listed in Reference 5.

Material Selection - Nonpressurized Areas

1. Flammability. Because of normal hazards associated with fabrication, checkout, and launch, materials selected shall be classified as self-extinguishing or nonburning in air per ASTM test procedures.

2. Weight Loss. Polymeric materials that have a weight loss in vacuum of more than one percent when tested per References 6 and 7 shall be avoided. Reference 7 may be used as a guide for classification and selection of candidate materials.

3. Volatile Condensable Material. Polymeric materials that have a VCM content of greater than 0.1 percent when tested per References 6 or 7 should be avoided when adjacent exposed functional surfaces may be affected by condensed polymeric materials. Reference 7 may be used to select materials that meet these requirements.

Configuration Control

1. Electrical cables shall not be exposed in the inhabited portions of the station but shall be protected by routing in covered trays, conduit, etc., to prevent chafing, shorting, breaking, and loosening of connections during normal activities or maintenance. Protective trays or conduit shall be non-conductive or shall be lined to prevent danger of chafing of insulation and possible shorting.

2. Conduits, wire trays, and passages such as utility tunnels shall be designed to prevent circulation of hot gases and smoke or propagation of flames between major compartments in the event of fire in one. Provisions for permanent or automatic fire, fume, and smoke barriers shall be considered.

3. Conduits, utility tunnels, environmental control ducting, etc., shall be designed to prevent the accumulation of dust or other debris. Provisions for inspection and cleaning shall be provided.

4. Storage of flammable materials, such as consumables, waste material, experiment supplies, etc., shall be in containers insulated from potential sources of ignition and so constructed to prevent propagation of fire to other structure or equipment if ignition of the contents occur.

5. Compartments and equipment shall be designed for the introduction of fire extinguishing nozzles in the event of fire in wiring or structure concealed behind equipment or panels. Fire extinguishing equipment, either automatic or manually operated, shall be accessible to all pressurized areas of the structure.

References

1. NR Process Specification MA0615-012, Combustion Rate Testing on Non-Metallic Materials (TM) and Configurations (TC) for Manned Spacecraft - Apollo CSM.

2. MSC-PA-D-67-13, Non-Metallic Materials Requirements.

3. NR Specification MC 999-0058, Approval of Non-Metallic Materials for Use in the Apollo Spacecraft, General Specification for.

4. MSC-NA-D-68-1, Non-Metallic Materials Design Guidelines and Test Data Handbook.

5. U. S. Dept. of Commerce NBS, Building Science Series 18, Smoke and Gases Produced by Burning Aircraft Interior Materials.

6. NR Process Specification MA0615-015, Vacuum Stability Testing of Polymeric Materials for Spacecraft Applications.

7. Stanford Research Institute Report - Polymers for Spacecraft Applications (15 September 1967).

2.2 OPERABILITY

2.2.1 Reliability

All OLS subsystems shall meet the following reliability requirements:

Number of Failures*	Subsystems Effect
1	Normal capability - no measureable reduction in performance
2	Full capability for crew safety and performance of most experiments
3	Full capability for crew safety. This situation can allow loss of capability to perform experiments.

*Failure as used here refers to any inflight replaceable unit (IFRU) or component inoperative because of malfunction or maintenance.

1. Capability shall be provided for performing critical functions at a nominal level (a) with any single component failed or (b) with any portion of the subsystem inactive for maintenance.

2. Capability shall be provided for performing critical functions at a reduced level (a) with any credible combination of two component failures or (b) with any credible combination of a portion of the subsystem inactive for maintenance and a failure of a component in the remaining subsystem functional elements.

3. Nontime critical functions ultimately critical to crew survival, require standby redundancy as a minimum.

4. Subsystem or component failure shall not propogate sequentially; equipment shall be designed to fail safe.

5. Redundant paths, such as fluid lines, electrical wiring, and connectors, shall be located so that an event that damages one line is not likely to damage the other.

6. Conservative factors of safety shall be provided where critical single failure point modes of operation cannot be eliminated (pressure vessels, pressure lines, valves, etc.).

2.2.2 Maintainability

1. Capability shall be provided to isolate those segments of the subsystem that require repair, replacement, or servicing such that the critical subsystem functions remain active, and hazard to personnel and contamination of the environment or subsystem is prevented.

2. Replaceable units will be designed to permit direct visual and physical access. Access for critical functions shall consider a pressure-suited crew. Connectors and couplings will be provided for ease of removal-replacement. Precision elements will be provided with suitable guides and locking to aid in replacement.

3. Provision shall be made for adjustment, maintenance, calibration, repair and replacement without tools where practical, standard tools where necessary, and special tools where essential.

4. Design features of the inflight replacement level and subsystem physical in place interfaces, shall consider potential wear and damage caused by multiple replacements.

5. Age-sensitivie materials will be avoided or protected for minimum degradation.

6. Provisions shall be made for movement of equipment and material via tracks, guides, or other constraining devices with space and friction controls to minimize potential damage to adjacent areas and hazard to personnel.

7. Design of hardware specifically required for crew habitability shall provide conservative factors of safety both in construction and mechanical securing.

8. Subsystem hardware shall be designed for shirtsleeve or IVA maintenance, both scheduled and unscheduled.

2.2.3 Useful Life

1. The OLS shall be designed for a minimum operational life of 10 years with resupply of consumables and replaceable items of equipment. This operational life may be obtained through long-life design and in-place redundancy for critical equipment whose failure could disable the OLS or imperil the crew.

2. Age-sensitive materials will be avoided or protected for minimum degradation. Consideration shall be given to state-of-the-art for material selection and related design characteristics such that wearout will not degrade performance beyond acceptable tolerance(s) within subsystem life cycle requirements.

2.2.4 Environments

Induced

Any OLS induced environmental model is a strong function of the natural environmental criteria presented in NASA TMX-53685, the OLS configuration, and the trajectory and operational characteristics of the launch vehicles employed. Since at the Phase A level it is not possible to define the launch vehicle that will be employed to boost the OLS into earth orbit, its trajectory or operational characteristics, an induced environmental model cannot now be established for the OLS.

Natural

The natural environment criteria for the OLS from ground operations through lunar orbit/lunar surface operations is specified in NASA TMX-53865, "Natural Environment Criteria for the NASA Space Station Program" (Second Edition, August 20, 1970). A brief outline is presented below of the applicable natural environment criteria given in NASA TMX-53865.

Paragraph No.	Title
Section I	Pre-Launch, Launch and Inflight Environment
1.1	Gas Properties
1.2	Winds
1.3	Additional Information

Paragraph	Title
Section II	Earth Orbital Environment
2.1	Atmospheric Gas Properties
2.2	Ionosphere
2.3	Radiation
2.4	Meteoroid Environment
2.5	Geomagnetic Environment
2.6	Solar Cycle Predictions
2.7	Astrodynamic Constants
Section IV	Lunar Environment
4.1	Atmospheric Environment
4.1.1	Gas Properties
4.1.2	Radiation Environment
4.1.3	Meteoroid Environment
4.1.4	Geomagnetic Environment
4.1.5	Astrodynamic Constants of the Moon*
4.2	Lunar Surface
4.2.1	Optical Properties
4.2.2	Additional Information

The R2 and L5 lunar gravitational models used for Phase A OLS orbital analysis were adequate for the purpose, but future work should use the LM-1 model.

2.2.5 Human Performance

Flight Crew

The OLS shall be under the authoritative control of one man who is responsible for the safety and operation of the vehicle. The nominal crew consists of 8 men who represent a range of technical and scientific disciplines and whose prime function is to develop and achieve experiment objectives. In general, crew skills are identified in terms of flight operations crewmen, support technicians, and scientists and experiments. The mission will begin with a developmental phase to verify vehicle performance characteristics together with a validation of station operations and safety procedures. In broad terms, this will be followed by a phase for development of operations, then a final phase of essentially steady-state autonomous operational activity. At a slower pace, the experiments activity will generally evolve from the initiation of techniques to scientific investigations and applied space sciences. The crew mix and functions will evolve in accordance with these phases and with varying station configurations.

*The LM-1 Gravitational Potential Model described in NASA letters 69-FM49-323 and 69-FM47-329 should be used rather than that in Section 4.1.5.2 of TMX 53865.

Crew Participation. The crew will be freed of routine operations to the greatest practical extent by the use of automated systems. Crew responsibilities are as follows:

Checkout and status monitoring of onboard subsystems and experiments

Fault isolation, maintenance, calibration, and repair of onboard subsystems and experiments and other equipment

Spares and expendables, inventory and control, and configuration management

Monitoring and control of experiment activities, evaluation and editing of raw data to delete nonsignificant information, onboard data processing and data reduction as required, and assignment of transmission priorities and modes

Safety, damage control, corrective action, and escape

Command and control of the station, including daily scheduling of operations, experiment and application activities, work, rest and recreation cycles, and the assigning of crew duties

Guidance, navigation, and control of station, co-orbiting experiment modules and the terminal rendezvous and docking phases of both manned and unmanned logistics spacecraft

Command and control of the space tugs for normal lunar surface sortie and logistics operations as well as emergency rescue operations

2.2.6 Transportability

Ground Handling and Transportability

Full design recognition shall be given to the durability requirements of core module equipment and subsystems during preflight preparation. Wherever possible, equipment and modules shall be designed to be transported by common carrier with a minimum of protection. Special packaging and transportation methods shall be required to prevent system penalties.

2.3 SYSTEM SAFETY

2.3.1 Ground Rules

1. Capability shall be provided for performing critical functions at an emergency level until the affected function can be restored or the crew returned to earth,

   a. With any one pressure isolatable volume inactivated, isolated, and vacated because of an accident or

b. With any credible combination of a subsystem inactivated as a result of an accident and a portion of a redundant or backup subsystem inactive for maintenance

2. The capability shall be provided on the OLS for the following:

   a. Detection of malfunctions and/or hazards

   b. Tracing to the failed replaceable unit

   c. Display of information to the crew necessary for corrective action

3. For those malfunctions and/or hazards that may result in time-critical emergencies, provision shall be made for the automatic switching to safe mode of operation and for caution and warning of personnel.

4. Range safety requirements at Kennedy Space Center and the Air Force Eastern Test Range shall apply. Waivers required to meet mission requirements will be identified.

5. Escape vehicles shall be capable of safely remaining in orbit until an acceptable earth-return opportunity is available.

6. If men are required in the OLS mission module during prelaunch preparation and testing, adequate and multiple escape routes shall be available.

7. At least two egress paths shall be available from each pressurizable volume for emergency egress of personnel during manned ground operations.

8. A man performing extravehicular activity shall be able to gain unassisted access to the escape vehicle.

9. Potentially explosive containers such as high pressure vessels or volatile gas storage containers shall be placed outside of and as remotely as possible from personnel living and operating quarters and wherever possible isolated and/or protected.

10. Emergency suits required in the OLS mission module shall be in readily accessible locations.

2.3.2 Criteria

1. Two or more entry-egress paths shall be provided to and from every pressure isolatable compartment or other area with restricted access.

2. Provision shall be made for the protection and survival of the whole crew at an emergency level during solar storms.

3. Provision shall be made for the protection and survival of the whole crew at an emergency level following a credible nuclear radiation accident until escape or rescue can be effected.

4. A margin of consumables shall be provided onboard and sufficient for performing critical functions at a reduced level following:

   a. The nonarrival of any one planned logistics vehicle

   b. Any credible accident that renders one pressure isolatable volume unavailable.

5. Provision shall be made for emergency medical treatment for durations compatible with the rescue-escape and earth-return provisions.

6. Provision shall be made for the restraint of irrational crew members.

7. Emergency OLS crew overload provisions shall be provided for the LSB crew in the event of LSB emergency or for additional OLS or LSB crew in the event of RNS failure in lunar orbit.

8. Provision compatible with the emergency medical provisions shall be made for the emergency return of sick or injured crewmen to earth.

9. The safe environment and the safe operational status of activated subsystems within the orbiting vehicle shall be verified prior to personnel entry initially and prior to reentry following temporary evacuation of the whole vehicle.

10. Deployment and initiation of operations considered hazardous shall be checked out from a safe location before exposing crewmen to the potential hazards.

11. All EVA shall be conducted by using either of the following:

    a. The "buddy system"

    b. Performing EVA within visual range of a suited crewman ready to exit

12. Provision shall be made for the return of a crewman incapacitated while performing EVA.

13. Provision shall be made for the containment and/or disposal of radioactive or otherwise toxic contaminants following credible accidents.

14. Provisions shall be made for containing (i.e., confining) and controlling (i.e., restoring to a safe condition) emergencies, such as fires, toxic contamination, depressurization, structural damage, etc.

15. All walls, bulkheads, hatches, and seals requiring pressurization for manned entry shall be readily accessible for inspection and repair by a crewman in a pressurized suit.

16. High-energy release equipment, such as pressurized tanks, propellants, etc., shall be located or protected so that a failure of one will not propagate to others.

17. Design and/or operational provisions shall be made so that no credible combinations of (a) an accident and two components inoperative or (b) three components inoperative (i.e., components within the subsystem or combinations of subsystem due to either malfunction and/or a single maintenance action) will cause the following:

    a. Loss of ability to man the OLS

    b. Loss of personnel on the ground or in orbit

2.3.3 Credible Accidents

The OLS shall be designed and operated so that crew survival will be ensured following the accidents defined in the following paragraphs.

Fire. Concern here is for a fire in an area containing subsystems equipment, electrical wiring, or laboratory equipment, which damages and puts out of commission all unprotected operating equipment in a compartment. A compartment, for this purpose, is a space that can be closed off by doors and hatches but which need not be air tight or pressure tight. Flame propoagation will be confined to the one compartment. Sufficient smoke/fumes will be produced to require rapid evacuation of the affected compartment by personnel. Personnel on other decks will be able to continue normal operations but will require face masks to enter the affected deck. The opening of hatches and other openings to the affected deck will be minimized for 24 hours while fumes are present. Electrical cable service conduits, plumbing lines, and ducts may temporarily become inoperative (e.g., power will be removed from electrical cables, fluid transfer will be interrupted, etc.) but will not be affected by the fire if they were designed for fire protection and will be brought on-line again after a system checkout -- within approximately an hour. Similarly, operating equipment specifically designed for protection from fire will be temporarily inactivated but will be brought on-line again after checkout.

Mechanical Damage. Mechanical damage is defined as that caused by a collision inside the vehicle with loose out-of-control masses. A momentum equivalent to a 50-pound mass moving at 2 feet per second will be involved. The collision may occur with any equipment exposed to a collision path (i.e., no intervening equipment) of approximately five feet or more but not to primary structure. The damage will be confined to the equipment within a 2-foot radius of the impact point. All equipment, cables, fluid lines, ducts, etc., will be damaged and put out of commission until they can be repaired and/or replaced, except equipment specifically armored for protection against collision.

Explosion. This is defined as an explosion of 0.025 pound TNT equivalent that released 50 Btu of energy in the form of heat, shock waves, and kinetic and thermal energy of shrapnel. Damage will be confined to one compartment (see previous definition on Fire) and will consist of overpressure, heat, shrapnel, and atmospheric contaminants. All equipment in the compartment will be damaged and made inoperative, unless armor plated for protection against this type of explosion. The equipment will require repair and/or replacement, depending upon the damage such an explosion can produce. Further hazards that can result in the compartment by such an explosion, such as fire, etc., should also be considered as part of this accident. Walls and primary structure or equipment outside the affected compartment will not be damaged.

Loss of Pressurization. This is defined as a loss of pressurization in a pressure volume caused by an accidental penetration of an outside wall or bulkhead, by a faulty relief valve, or by a leaking pressure seal. The time from detection of the failure to reaching a nonhabitable environment will be approximately $\gtrsim$ 0.1 hour for a pressure volume $\gtrsim$ 10,000 ft^3, corresponding to a 2-1/2-inch diameter hole. This accident will require evacuation of the affected pressure volume and the subsequent detection and repair of the source of leakage by two IVA personnel. No equipment will be damaged by the accident itself. But because the whole of the affected pressure volume will be exposed to vacuum conditions, sensitive equipment may have to be deactivated to survive the period until repressurization.

Fluid Leakage. Leakage is defined as leakage of any gas or liquid produced, stored, or routed through the pressurized areas of the vehicle, including any chemicals used or that may be produced in experiments. The leakage may occur at any point through which the fluid is routed. The amount of leakage will vary with the provisions made for detection and with the provisions for stopping the leakage (dumping the fluid overboard, shutting off the process, transferring to another tank, etc.). This quantity should be defined for every potentially hazardous fluid onboard. Following detection, the leakage may be confined to the affected deck by restricting air circulation and providing a partial dump to vacuum in that deck. Damage to equipment (e.g., from corrosion, etc.) and the possible requirement to temporarily evacuate the deck must be considered separately for each onboard fluid.

Collision. This is defined as a grazing collision with another vehicle or with space debris that damages equipment outside the spacecraft such as RCS jets, radiators, solar panels, antennas, tanks, fluid lines, docking mechanisms, etc. The collision is not severe enough to cause a penetration of primary structure but may damage exposed equipment over a circular area of approximately 3-foot diameter. The damage will require maintenance, repair, and replacement to restore the function. If the equipment is not maintainable, repairable, and replaceable, the damage is to be regarded as permanent.

Personnel Loss. This is defined as the loss of any one man through injury, illness, or death. Provisions must be made for medical treatment until his return to earth and for cross-training to allow other personnel to take over duties necessary for crew safety.

Food or Water Contamination. This is defined as biological or toxic contamination of food or potable water supply. All similarly packaged food stored in any one area (e.g., all vacuum-packed food stored in one pantry) will be assumed unfit to eat. Similarly, all potable water in connected tanks also will be assumed toxic; however, the water may be reprocessed through the water purification system and the tanks decontaminated to render it potable.

Accident in a Hatch. This accident is defined as the loss of access to any one hatch assembly, door, or other personnel, or cargo transfer opening because of jamming of the mechanism, either open or closed, or because of obstruction by cargo or a localized hazardous situation (fire, chemical spillage, electrical hazard, etc.). The hazardous or nonaccessible area may extend over a volume of about 5 by 5 by 5 feet and may be situated anywhere within 5 feet of the edge of the hatch or opening. This accident is not to be considered credible where two independent methods for opening a hatch have been provided and where special provisions have been taken to avoid hazardous equipment in the vicinity of the hatch.

Incapacitated EVA or IVA Man. This condition is defined as an out-of-control and incapacitated man performing EVA or IVA. Rescue is required within 5 minutes by a companion already suited and conditioned to the suit atmopshere, who is waiting in an airlock or is also performing EVA or IVA.

Meteoroid Penetration. This is defined as meteoroid penetration of the primary structure. The results will be similar to an explosion, as described in a previous paragraph on Explosion, releasing 50 Btu of energy. Such a meteoroid has less than 0.001 probability of impact in 10 years, and the meteoroid is approximately 0.6 inch in diameter. Physical damage will be confined to one compartment (see definition on Fire) and will consist of finely divided molten high-speed shrapnel (from spallation of the inner wall). All equipment in the compartment will be damaged and made inoperative, unless armor-plated for protection against this type of shrapnel. Damaged equipment will require extensive repair and/or replacement. Further hazards that can result in the compartment by such an accident, such as fire, etc., should also be considered as part of this accident. The resulting penetration of the pressure wall will be 2-1/2-inches in diameter and will cause depressurization of the vehicle (assuming an air volume equal to that in both pressure volumes of a space station) to an unsafe level in approximately 0.1 hour or greater for a pressure volume $\geq$ 10,000 ft^3.

Loss of Electrical Power. This condition is defined as loss of the availability of electrical power from like type power sources (all solar panels, all fuel cells, or all batteries) in one pressure volume or all inverters in one volume as the result of an accident and/or a sequence of unexpected failures. The loss will be immediate with no advanced warning.

Atmospheric Contamination. This condition is defined as the atmospheric contamination by toxic or otherwise hazardous contaminants that will require personnel evacuation from one pressure volume within 2 minutes of detection. The affected volume will require either purging to vacuum and subsequent repressurization or, if the contaminant can be removed by the ECLSS, will require processing of the atmosphere for 2 days to restore a habitable environment. The other presssure volume will remain habitable.

Electrical Shock. This is defined as electrical shock to any one man while performing maintenance or working with electrical or electronic equipment or experiments. The shock may result in momentary (seconds to minutes) loss of performance capability by the man, to injury requiring the man's emergency return to earth, and/or loss of life.

Hazard in a Docked Module. This is defined as a hazard appearing on a docked cargo, experiments, or other module, which arises from any of the previously mentioned accidents occurring on the module, as applicable. The module is to be considered as a separate pressure volume from the point of view of isolation, containment, and control. If required, access to a depressurized or contaminated module will be by two EVA personnel, using a second hatch on the module for ingress.

OLS Abandonment. This is defined as a combination of accidents and/or subsystems degradation requiring the abandonment of the OLS by some or all of the occupying personnel. Such abandonment will not be a time-critical emergency but a deliberate abandonment planned over a period of days to months. The worst design case is when one of the separate pressure volumes has been evacuated and sealed off for up to 30 days because of major damage or contamination, and all personnel are in the remaining volume. Furthermore, if subsystems degradation becomes apparent in the latter volume, it will result in the decision to abandon. Such subsystems as are capable of survival must be set in a passivated or quiescent mode to ensure safe personnel escape and to minimize damage for possible reoccupation at a later date.

2.3.4 Safety Definitions

Accident	- An unplanned event that results in an unacceptable situation or operational mode
Containing a hazard	- Limiting the area and time over which a hazard extends
Controlling a hazard	- Reducing the hazard to a safe (i.e., nonhazardous) situation

Critical functions	- Those functions necessary for crew safety and mission continuation. In determining whether a particular function is or is not critical, its absence must be considered for the longest time period for which the function may be nonavailable following any credible combination of failures and/or accident.
Credible	- Within the assumed probability of occurrence for which it is desired to design and operate a system
Emergency level	- At a level sufficient only for crew survival
Escape	- Evacuation of personnel from a distressed vehicle using self-contained device(s) independent of outside assistance and the subsequent safe return to earth or to a space vehicle capable of safely sustaining the personnel
Failure (Criticality I)	- A single failure that could cause loss of personnel
Failure (Criticality II)	- A single failure whereby the next associated failure could cause loss of personnel, or a single failure that could cause return of one or more personnel to earth, or loss of subsystem function(s) essential to continuation of space operations and scientific investigations.
Hazard	- Any situation or condition that significantly increases the probability of injury to personnel or permanent damage to equipment
Catastrophic hazard (Category I)	- A hazard that could cause loss of personnel
Critical hazard (Category II)	- A hazard that results from a Criticality II failure or a hazard that could cause return of one or more personnel to earth or loss of function(s) essential to continuation of space operations and scientific investigations

Marginal hazard (Category III)	- All other hazards
IFMU (inflight maintainable unit)	- Any portion of a subsystem that can be mechanically and electrically inactivated in order to perform inflight maintenance
IFRU (inflight replaceable unit)	- Any portion of a subsystem that can be individually replaced in flight
Nominal level	- At the level planned for normal operations
Reduced level	- At a level lower than planned but still sufficient for limited mission accomplishment
Rescue	- Evacuation of personnel from a distressed vehicle using separately based vehicle(s) and the subsequent safe return to earth or to a space vehicle capable of safely sustaining the personnel
Restricted access	- Access to an area such that a single failure or accident could prevent safe crew passage through that path
Safe	- Free of hazards; mission success
Mission continuation	- The capability to perform a useful experiments program. For OLS subsystems, this means that all power, stabilization, information management, thermal control, laboratory facilities, life support for experimenters, etc., required to perform a useful experiment program are available. For experiments, this means that the experiments, experimenters, experiments modules, etc., required to perform a useful experiments program are available.
Performing critical functions at a nominal level	- This means that the capability exists in both the OLS and the experiments to perform the experiments program as planned while assuring crew safety.

Performing critical functions at a reduced level	- This means that some subsystems functions and/or experiments have been lost causing a significant reduction in the capability to safely perform a useful (i.e., worth doing, as opposed to aborting the mission) experiments program. "Significantly reduced" can mean the loss of major experiment or the nongainful employment of an experimenter onboard the station.
Performing critical functions at an emergency level	- This means that a useful experiments program can no longer be safely carried out, either because of loss of subsystems functions or experiments. The capability is still available, however, for the safe survival of onboard personnel until either (a) escape or rescue can be performed or (b) the failed functions can be restored by resupply, repair, and replacement (time duration for this will vary, depending upon the failures).

2.4 GENERAL GUIDELINES AND CONSTRAINTS

This section presents the general guidelines and constraints to be used in Orbiting Lunar Station (OLS) study and development efforts. The NASA MSC Statement of Work for Phase A Feasibility and Definition Study of Lunar Orbit Space Station (LOSS), dated 6 March 1970, is the primary source. Where applicable, results of concurrent contractural efforts of other Lunar Exploration Program elements have been used to provide general constraints.

1. The OLS operational date shall be 1983, and the operational life shall be 10 years.

2. The OLS shall provide a support capability to any point on the lunar surface. Rescue of crews from any point on the lunar surface shall be supported by the OLS.

3. The selected lunar orbit shall be maintainable with reasonable propellant expenditures.

4. The OLS shall be capable of supporting a capability for remote sensing of any point on the lunar surface.

5. Consumable resupply shall not be required more than once every six months.

6. The initial OLS shall be zero gravity. The design shall not prevent subsequent modification to an artificial gravity station.

7. The OLS shall have the capability to command, control, and monitor all lunar elements of the NASA integrated program, including remote control of manned or unmanned surface or orbital (lunar) vehicles.

8. The OLS shall be capable of autonomous operations to the degree necessary.

9. The OLS shall lend itself to the assembling of additional separately launched station modules to increase capability as required.

10. Provisions for emergency returns from the OLS shall be provided by the logistics system. Logistics spacecraft will normally remain docked to the OLS to provide emergency return for the crew.

11. The OLS is defined as a completely self-contained module with provisions for a crew and an experiments program.

12. Mission planning and systems designs shall minimize the overlap times of rotating crews.

3.0 MISSION REQUIREMENTS

3.1 GENERAL REQUIREMENTS

The Orbiting Lunar Station (OLS) is to be the United States' facility in lunar orbit required to satisfy a variety of scientific and technological objectives. The scientific and technology objectives will be satisfied by a series of experiments that will be established, supported, monitored or controlled, and maintained by the manned OLS. The OLS must provide the services, crew support, expendables, and operations to meet experiment objectives in lunar orbit. It will assist in meeting lunar surface scientific and exploratory objectives.

The OLS will be required to operate in several space regimes. Low altitude earth orbits of 200- to 400-n mi altitudes and 28.5 degrees to 55 degrees inclination will be required for checkout operations prior to translunar flight. The OLS will be manned while in earth orbit by a checkout crew for this purpose. The OLS will be unmanned during delivery to lunar orbit. The OLS shall be capable of meeting specified performance levels during operations in any of the required space regimes. The OLS shall be capable of acquiring any desired attitude throughout the mission, and self-support attitude demands shall not constrain experiment operations. The OLS shall be capable of operating at any lunar inclination at altitudes of 45 to 80 n mi. As a result of the orbit determination study (see Section 2.0, Volume II), the design to orbit is 60 n mi polar.

3.2 BASELINE MISSION DESCRIPTION

The major mission phases that define the baseline operations of the OLS are discussed in the following paragraphs. For study purposes, the mission is initiated at the start of countdown and continues through dispersal of the OLS at mission termination.

3.2.1 Countdown

Countdown of the OLS will begin when the OLS is mated to the launch vehicle and launch time established. The launch is to be unmanned, and there shall be no requirement for onboard crew participation during countdown operations. The OLS shall not require countdown procedures, operations, or facilities that constrain use of programmed facilities or launch vehicles. Countdown is terminated upon umbilical separation at launch.

3.2.2 Ascent-to-Earth Orbit

Ascent-to-earth orbit is initiated at launch and terminates at earth orbit insertion. The OLS is launched unmanned, and flight path and attitude control are provided by the launch vehicle. The nominal OLS earth orbit insertion will be to a circular orbit of 258 n mi at 31.6 degrees inclination. OLS subsystems will be quiescent during ascent with only those active functions needed to assure range safety and required data recovery.

3.2.3 Earth Orbit Operations

Earth orbit operations commence at earth orbit insertion and end with translunar injection. During earth orbit the OLS must interface with the systems used to transfer the OLS from the launch vehicle to the cislunar shuttle. The earth orbital phase will consist of separation from the orbit insertion stage, attitude control and activation of rendezvous aids, subsystem checkout, rendezvous and docking (Tug, CPS, RNS, or EOS), and verification of integrity by the checkout crew. The OLS will provide unmated attitude control capability, life support, electrical power, communications, and checkout provisions to the minimum level required for checkout.

3.2.4 Translunar Flight

Tranlunar flight starts with translunar injection and terminates with lunar orbit insertion. At completion of earth orbit checkout, the OLS is unmanned and quiescent. Flight path and attitude control of the OLS is provided by the cislunar shuttle (RNS or CPS). The OLS will provide normal subsystem status information via the RNS or CPS communication systems.

3.2.5 Lunar Orbit Insertion

Lunar orbit insertion is initiated at transfer from the translunar orbit by the cislunar shuttle and terminates when the specified orbit is achieved. The nominal lunar orbit is polar and at 60-n mi altitude. The OLS is unmanned during lunar orbit acquisition, and the flight path and control functions shall be performed by the RNS (or CPS).

3.2.6 Unmanned Lunar Orbit Activation

Lunar orbit operations commence with the initiation of OLS premanning checkout and terminates when the operational crew docks with the OLS. While unmanned, the OLS must perform attitude control, subsystem activation, remote checkout, and rendezvous/docking support.

In addition to the nominal unmanned mission requirements, the OLS shall provide for unmanned operational capability after manning and before mission termination in the event of emergencies or to support experiment objectives.

3.2.7 Manned Lunar Orbit Operations

Manned lunar operations shall be defined as beginning when the operational crew docks with the OLS. The OLS's primary mission operations occur during this phase. The manned lunar orbit operations involve functions required to provide quarters and safety for the crew and related self-support capabilities and support of other program elements and experiments.

3.2.8 Self-Support Operations

Self-support operations include those activities and functions needed to maintain crew safety and health, orbit position, orientation, subsystem status and operations, scheduled and unscheduled maintenance, and otherwise provide quarters and support of the OLS exclusive of experiments. The OLS self-support functions shall place minimum constraints on the operation of experiments.

Self-support operations will include the following recurring functions:

1. Communication schedules as related to life support, safety, or flight operations
2. Navigation and guidance as related to the support of logistic mission, stationkeeping, and routine OLS command and control. Observations of lunar landmarks, the solar system, and stellar environment will be required.
3. Crew cycles and life support and medical provisions to assure efficient station operation, crew traffic patterns, and safety
4. Attitude control functions which do not constrain or contaminate the experiments
5. Maintenance and servicing operations
6. Logistic operations to include crew, cargo, and experiment package transfer
7. Environmental protection for internal crew and experiments
8. Structural integrity and characteristics required to meet safety, technical, and operational requirements
9. Electrical power for self-support operations and emergencies

Self-support operations will require long-life systems that have ease of maintenance and/or replacement. The OLS shall be self-sufficient with life support systems capable of supporting normal and emergency operations. Normal overlap of crew sequencing will be accomplished as defined in Section 7.0 of Volume II. A continuous emergency return capability for all crewmen on the OLS and docked space tug shall be required.

3.2.9 Lunar Surface Support

The OLS shall provide the capability to support experiment and scientific facility development on the lunar surface. The OLS shall provide command, control, location determination, readout, and communications with manned and unmanned lunar surface vehicles and bases. Operational interface capability shall be provided with the following:

1. Tug (lunar orbit to surface/surface to orbit, manned or unmanned)

2. Lunar surface vehicles (unmanned)

3. Surface experiment modules prior to lunar surface delivery

4. Orbiting data relays or measurement devices in support of lunar surface operations

5. Lunar surface base (manned)

Functions shall be provided related to activation, checkout, and maintenance of items prior to lunar delivery. The OLS shall provide crew provision for habitation, rest, recreation, medical, and sustenance of personnel operating to or from the lunar surface in normal and emergency modes.

3.2.10 Experiment Support

The OLS shall provide docking, airlock, passageway, communication, atmosphere, crew, safety, and other interface provisions necessary for safe operation of attached or detached experiments. The OLS shall support command, control and process scientific and technological experiments in lunar orbit. OLS self-support operations shall place minimum constraints on experiment operations. The OLS shall be capable of assuming any attitude orientation and rate (consistent with crew and expendable limits) needed to meet experiment objectives. OLS operations and equipment in support of experiments shall be of long life and shall contribute to the development of planetary exploration capability.

3.2.11 OLS Mission Termination

The OLS mission termination phase will begin when the last experiment or technology data acquisition is terminated and will end when the final disposition of the OLS is achieved. The OLS mission termination shall not present hazards or subsequent operational constraints on the other space or lunar exploration activities.

4.0 EXPERIMENT PROVISIONS REQUIREMENTS

Experiment provisions provide the structure, electrical power, environmental control, pointing and stability control, command and control, monitoring, data handling, docking, operational support, and crew provisions necessary for OLS support of experiments. In other words, the experiment provisions requirements result from interfacing with the OLS subsystems.

4.1 FUNCTIONAL REQUIREMENTS

There is no specific functional grouping of major assemblies and hardware items that comprise experiment provisions. The requirements delineated in this section are a summation of the interface requirements imposed on the functional subsystems to support all experiment operations.

4.2 PERFORMANCE REQUIREMENTS

Experiment provisions have no specific performance requirements as a subsystem because it is comprised entirely of interfaces with the various station subsystems. Performance requirements shall be met by the supporting subsystems consistent with the requirements of paragraph 4.4.*(1)

4.3 OPERABILITY

4.3.1 Reliability

See Section 2.2.

4.3.2 Maintainability*(2)

1. Capability shall be provided to isolate those segments of the experiments equipment and subsatellites that require repair, replacement, or servicing.

2. Provision shall be made for adjustment, maintenance, calibration, repair and replacement without tools where practical, standard tools where necessary, and special tools where essential. See Section 2.2.

4.3.3 Useful Life

See Section 2.2.

*For rationale, refer to specified item number in Section 4.5

4.3.4 Environment

See Section 2.2.

4.3.5 Human Performance

See Section 2.2.

4.3.6 Safety

See Section 2.3.

4.4 MAJOR INTERFACES

This section specifies the interface requirements that the experiment provisions shall have with the various OLS subsystems.*(1)

4.4.1 Structures

Integral Floor Space*(2)

Data Analysis Laboratory	70 square feet
Geochemistry Laboratory	100 square feet
Photography Laboratory	70 square feet
Experiments Control Center	45 square feet

Airlock Laboratory

The structure shall make provisions for an airlock laboratory located in the vicinity of the experiment deck for integral experiment use as follows: *(2)

1. The airlock shall be sized to accommodate all remote sensors (11,000 through 15,000 series equipment items) and sub-satellite servicing (60,000 series equipment items) in accordance with the Experiment Operating Plan. Airlock minimum dimensions shall be 5 feet diameter and 10 feet long.*(7,12)

2. The airlock shall be capable of being pressurized and de-pressurized three times per year.*(3)

3. The airlock shall permit shirtsleeve crew access to film and tape cassettes while all sensors are in a deployed mode.*(4)

4. The airlock shall contain the following utilities: *(2)

   a. Electrical power

*For rationale, refer to specified item number in Section 4.5

b. Thermal control (of instruments via environmental control/life support subsystem)

c. Information subsystem (ISS) data and communication hardlines

d. O_2 and N_2 (instrument)

e. Cryogenics

f. Propellant transfer provisions for N_2 and N_2H_4 for subsatellite servicing

g. Subsatellite docking provisions (as required to satisfy the Experiment Operating Plan)*(5). Docking provisions shall include a docking port with a minimum 5-foot diameter opening that will permit crew egress/ingress for EVA activities. (Refer to Sections 3.0 and 5.0, Volume II, for rationale.)

5. The airlock shall be located such that deployed sensors can view both the lunar surface and the celestial sphere.*(2)

6. The following utility hookups shall be provided at the subsatellite docking interface: *(2)

   a. Electrical power

   b. Thermal control

   c. ISS data hardlines

   d. O_2 and N_2 (for instruments)

   e. Propellant transfer - N_2 (blowdown) and N_2H_4 (positive expulsion)

Free-Flying Subsatellites

The structure shall withstand the docking forces of the free-flying subsatellites.*(6)

Deployed Experiment Sensors

Provisions shall be made for deployed experiment sensors to have an unobstructed view from nadir to five degrees above the lunar horizon.*(2)

*For rationale, refer to specified item number in Section 4-5

Onboard Experiments

The structure shall provide a location close to OLS reference for on-board experiments that require base-motion isolation for greater accuracy or tracking capability. Where possible, experiments with similar pointing, tracking, and view angle requirements will be mounted on the same gimbal structure,*(2)

Mounting Accommodations

The structure shall provide suitable mounting accommodations for experiments so that installation, maintenance, and replacement may be accomplished without EVA.*(6)

4.4.2 Reaction Control Subsystem

The RCS shall provide the following propellant for subsatellites per 180 days: *(7)

N_2 storage	455 lbm
N_2H_4 storage	7811 lbm

4.4.3 Environmental Protection Subsystem

Environmental protection shall be provided for integral experiments as part of the normal protection provided for the OLS. Radiation protection shall be provided for stored experiment film to the extent required. Environmental protection of in-use equipment and of subsatellites shall be provided by the experiments.*(6)

4.4.4 Electrical Power Subsystem*(10)

The electrical power subsystem shall have interfaces with and support requirements for experiments as follows: *(2)

> Average power of 4 kw; maximum sustained power demand of 6 kw for less than 1 hour with a frequency of occurrence of not more than twice in 24 hours; and peak power of 7 kw for a duration less than 1 minute, the frequency of occurrence shall not be more than twice per hour. Sequencing of operation of experiments shall be required to preclude a power demand in excess of the power allotted above.

*For rationale, refer to specified item number in Section 4.5

4.4.5 Environmental Control/Life Support Subsystem

Atmosphere

The OLS ECLSS shall provide atmospheric gas circulation capabilities to provide a shirtsleeve environment in all experiment areas that require human habitation.*(6)

1. Pressurization, depressurization, and leakage

   Airlock experiments-capabilities for pressurizing and depressurizing the airlock from an onboard assembly shall be provided. Airlock capabilities shall be as specified below: *(7, 12)

Volume	200 cubic feet
Pressurization time	To be determined from operational considerations
Depressurization time	24 hours maximum*(2)
Frequency of use	Three times per year*(3)
Gas composition	Same as OLS*(6)

2. Temperature Control. The OLS shall provide temperature control between 65 and 75 F for integral experiments. Capability shall be provided in the experiments area to supply air selectable between 60 and 75 F. The OLS atmosphere shall accommodate 1000 watts of sensible heat maximum from the integral experiments. (Sized on the basis of 25 percent to the atmosphere of a maximum 4000 watts).*(6)

3. Pressure Control. The OLS shall provide total pressure control and oxygen partial pressure control for experiments to the same condition as the OLS atmosphere. The OLS and experiments atmosphere shall be controlled to 14.7 psia (with variation to 10 psia allowable) and oxygen partial pressure at 3.1 psia. Experiment pressure requirements different from the OLS shall be provided by experiments. *(2, 6)

4. Humidity Control. The OLS shall provide atmosphere at 8 to 12 mm Hg partial pressure of water for integral experments. Humidity control to a different level shall be provided by the experiment. Excessive experiment-caused humidity (greater than approximately 0.5 lb/hr or nonhuman water to the atmosphere) shall be removed by experiment facilities.*(2, 6)

*For rationale, refer to specified item number in Section 4.5

5. Contamination Control. Toxic, corrosive, or bacteriological contaminants shall be removed by the experiments before the atmosphere is returned to the OLS system. The OLS contaminant control assembly may be utilized by experiments for the control of contaminants with maximum generation rates as specified in final report GDC-DAB-67-003, Vol. VI ECLSS, Study for BSM Preliminary Definition, dated October 1967.*(6)

Active Thermal Control

The OLS shall provide active temperature control between 65 and 75 F for integral experiments sufficient to accommodate 4000 watts maximum dissipation.*(2, 6, 8)

Water Management*(2)

1. Storage and/or generation capability for supplying 35 lb/day maximum of potable water shall be provided by the OLS ECLSS. The water shall have the same potability and purity requirements as the OLS (NASA-MSC specification PF-SPEC-18, Command Module/Lunar Module Potable Water Specification, 25 June 1969).

2. Experiment water requirements with a different purity requirement shall be considered an experiment expendable item and handled as a logistics supply material.

3. Experiment water which cannot be accommodated by the OLS distillation reclamation assembly because of unused chemicals or contaminants shall be considered a waste product and treated as a logistics return material. Water makeup for such waste water shall be treated as an experiment logistics supply item.

Waste Management

The OLS ECLSS shall provide capability for processing either individually or collectively a total of approximately 30 lb/month of waste and trash materials from experiments.*(2)

Hygiene - Not Applicable

Food Management

Preparation of all special human, plant, or animal nutrients shall be provided by the experiment. The ECLSS shall provide crew food storage and preparation capabilities. Any special freezer, refrigerator, and oven requirements shall be provided by the experiments.*(2)

*For rationale, refer to specified item number in Section 4.5

4.4.6 Information Subsystem

1. An experiment control center shall be provided having command and control and display capabilities. The experiment control center shall also serve as a backup control center for the OLS. Backup capabilities for the experiment control center shall be provided in the OLS primary control center.*(2)

2. The interface between the ISS and free-flying subsatellites shall be via RF link. The ISS shall provide commands, computer data, and ranging signals. The subsatellite shall provide, upon command, turn around ranging signals, subsystem data, and experiment data. The interface between the ISS and docked subsatellites shall be via coaxial cables. This shall connect the digital data distribution bus to the subsatellite with suitable modems. The ISS shall be capable of supporting two subsatellites on station. The interface between the ISS and integral experiments shall be through remote acquisition and control units (RACU's) and/or modems. The OLS information subsystem shall provide the command control capability, data acquisition, processing, storage, relay capability, display capability, and the checkout and fault isolation capability required to support all experiment functional program elements as outlined herein.*(2, 7, 11)

   a. Data types

      (1) Soft data may take the form of analog data, digital data, or television displays. The responsibility for digitizing and formatting rests with the OLS information subsystem.

   b. Data rate/quantity*(11)

(1)	Digital - instantaneous peak		6×10^6 bps
		Daily (maximum)	3.5×10^{11} bpd
		Daily (average)	1×10^5 bps
(2)	Television - Station CCTV (2.9 - 4.5 mHz)		3 channels
		Station to surface (4.5 mHz)	1 channel

      (3) The ISS shall be capable of acquiring data from lunar orbiting subsatellites for distances up to line-of-sight.

*For rationale, refer to specified item number in Section 4.5

c. Storage capability

Operating memory	18K words
Mass storage	1 megawords
Tapes	180 pounds
Hard copy	180 pounds

d. Command and control

Discrete commands	1500
Variable commands	80 eight-bit commands

The capability for command and control of lunar orbiting subsatellites shall be provided for distances up to line-of-sight.

e. Displays

Types: Graphic display device. Provision is required for curve tracing and plotting.

Signal light

Meter

TV (includes closed-circuit TV)

f. Data processing capability - 1×10^{10} bpd

g. Timing - timing signals shall be provided with a stability of 0.01 part per million at a rate of at least 1 kHz.

4.4.7 Guidance and Control Subsystem*(2)

Attitude Requirements in Lunar Orbit

The OLS G&C shall be capable of maintaining station axes fixed with respect to inertial coordinates in X-POP inertial flight mode within $\pm$ 0.25 degree.*(8, 9)

The OLS G&C shall be capable of maintaining station axes within $\pm$ 0.25 degree in lunar referenced attitude hold with +Z axis at nadir in $\overline{\text{X}}$-POP level mode on a continuous basis, except when it is in the inertial flight mode previously specified. For experiments, the station will fly with the -Y axis in the direction of the velocity vector,*(8, 9)

The station also shall be capable of operating in a fine pointing mode for periods up to 30 minutes, with an accuracy with respect to nadir of $\pm$ 0.1 degree.*(8, 9)

*For rationale, refer to specified item number in Section 4.5

Ephemeris Accuracy Requirements

Uncertainty in the knowledge of station orbit position and velocity shall be within the following limits: *(9)

Altitude	± 330 feet, 1 sigma
In-track	± 850 feet, 1 sigma
Cross-track	± 490 feet, 1 sigma
Orbit velocity	± 0.4% (25 fps), rms

Information Requirements

The G&C shall provide the following information to the ISS in support of the experiments: *(2)

Current station attitude and rate and reference attitude alignment

Position vector of targets-of-opportunity in lunar centered inertial coordinates

Current station estimated state vector

Experiment to G&C reference calibration data

Guidance targeting and delta V commands for rendezvous, docking, deployment, and stationkeeping of free-flying subsatellites

4.4.8 Crew Habitability

1. Crew support for experiment operations equivalent to five men working one 10-hour shift per day shall be provided.*(6, 8)

2. The crew skill mix shall be as identified in the Experiment Operating Plan. The OLS crew required for experiment operations shall have the skills necessary to activate, operate, maintain, record, and analyze data, and deactivate the onboard experiments for each scientific discipline represented.

4.4.9 Docking Provisions

Docking provisions shall provide for logistic support of experiment resupply during normal operations by providing access to the logistics spacecraft.

*For rationale, refer to specified item number in Section 4.5

4.5 RATIONALE

1. Requirements in this section are based on an analysis of the individual scientific experiments, the equipment required to conduct them, and the schedule to which they will be operated as defined in the Experiment Operating Plan. Whenever applicable, EOSS study results were reviewed in specifying OLS requirements.

2. This requirement was established to satisfy the OLS science objectives and the Experiments Operating Plan based on Apollo and EOSS experience.

3. Based on the estimated airlock utilization from the Experiments Operating Plan.

4. Required to preclude excessive airlock depressurizations and repressurizations.

5. Shirtsleeve access to the subsatellites is required for data retrieval and subsatellite servicing.

6. Necessary from crew safety, habitability, and operability considerations.

7. Required for subsatellites in accordance with the Experiments Operating Plan.

8. Based on the first iteration of experiment requirements with operational requirements as reflected in the Experiments Operating Plan.

9. Station attitude control and stability requirements arise from integral experiments employing passive and active remote sensors. For example, nonimaging sensors such as the microwave radiometer (11007) and the radar altimeter/scatterometer (11041) must be provided with attitude control ranging from 0.1 degree to 0.25 degree to accomplish the requirements of the experiments using them (5019 and 5020, respectively). This enables them to obtain the required spatial discrimination ranging from 200 to 500 meters on the lunar surface from an altitude of 60 n mi (100 km). Imaging sensors such as the high resolution camera (11042) used in Experiments 5002, 5014, and 5016, impose severe stability limits on the station in order to achieve required surface resolution and avoid image smear. At an altitude of 100 km, an exposure of 0.01 second and a required ground resolution of 1 meter, the spacecraft rate must be limited to 0.05 degree per second. Even more severe requirements result when higher resolutions are (occassionally) required. This results in the fine pointing mode requirement of 0.01 degree per second.

Ephemeris accuracy requirements result from the requirement to be able to associate nonimaging sensor data with the area being sensed (field of view) to within the specified limits (1 n mi) in post-flight data analysis. Also, subsatellites sense magnetic phenomena and electric fields, atmosphere, and gravity, that vary significantly over distances of 10 to 100 miles, and, therefore, the OLS must be capable of establishing their orbits to $\pm$ 1 nautical mile (all directions).

10. The power profile prepared from the preliminary OLS Experiments Operating Plan indicates a maximum average power consumption of 3.2 kw. This has been rounded up to 4 kw in these requirements to provide growth capability. A power level of 6 kw is required to handle loads that occur occasionally for periods of less than one hour. The same 4 kw is assumed dissipated as heat and sizes the active thermal control requirement of the ECLSS.

11. The data rate profile prepared from the preliminary OLS Experiments Operating Plan indicates a maximum sustained data rate of 4.5×10^6 bits per second. This has been rounded up to 6×10^6 bits per second in these requirements to provide growth capability. Subsatellite data processing accounts for this requirement. An average rate of approximately 10^4 bits per second would result if subsatellite data management were not an OLS function. All other ISS requirements (storage, command/control, displays, data processing, and timing) result from scaling comparable EOSS study data. (See also Volume I, Section 4.0)

12. A 5-foot diameter by 10-foot deep airlock is required to allow servicing of Pioneer-class subsatellites within the airlock.

5.0 CREW AND HABITABILITY PROVISIONS REQUIREMENTS

The crew and habitability provisions include crewmen of requisite skills and their personal effects and equipment; the crew furnishings necessary for crew comfort, recreation, medical care, and exercise. All special life support and emergency crew survival equipment is supplied by the ECLSS. The provisions also include the internal cargo handling and transport provisions and the restraint devices required for human manipulation and safety as well as the crew's general equipment, including their tools, mobility aids, and radiation monitoring devices. A block diagram of the crew and habitability provisions is shown in Figure 5-1.

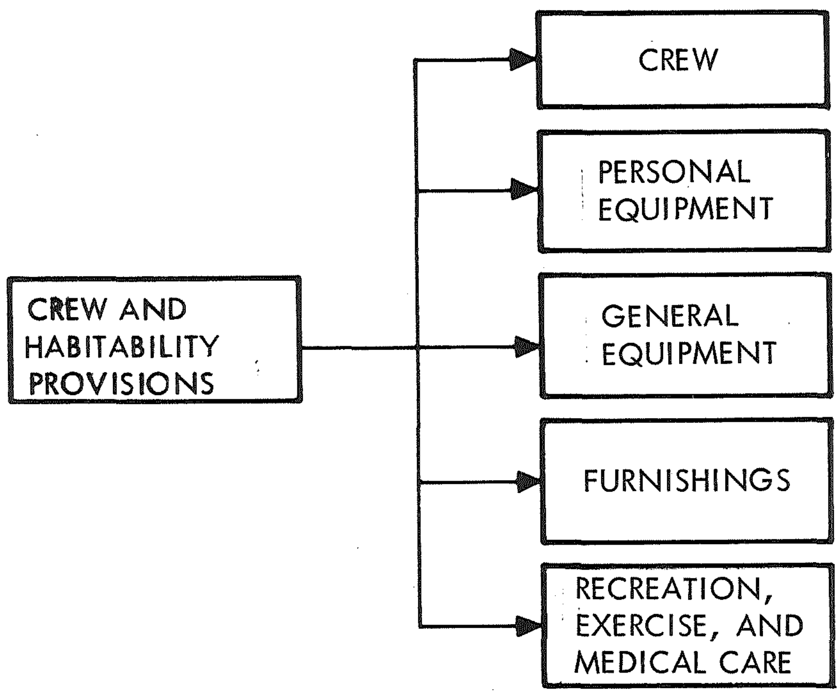

Figure 5-1. Block Diagram of Crew and Habitability Provisions

5.1 FUNCTIONAL REQUIREMENTS

The crew and habitability provisions include those items necessary to support, maintain, and operationally assist the OLS crew in the performance of mission functions and objectives. The crew and habitability provisions for the OLS include the following:

1. The crew
2. Crew personal equipment
3. Crew equipment
4. Crew mobility aids
5. Crew restraint devices
6. Equipment restraint devices
7. Cargo handling/transport provisions
8. Tools
9. Radiation monitoring devices
10. Crew furnishings
11. Recreation
12. Exercise
13. Medical care

5.2 PERFORMANCE REQUIREMENTS

The crew equipment items shall meet the performance requirements delineated in the following paragraphs. These requirements are arranged in the same sequence as the functional requirements defined in paragraph 5.1.

5.2.1 Crew

1. The OLS shall provide the capability to support a nominal crew complement of 8 crewmen with a maximum capability to support 20 crewmen for 55 days for LSB rescue.*(1)

2. Pertinent crewman dimensions for a 5th and 95th percentile crewman (presented in Figure 5-2) shall be used for developing OLS interior arrangements. Standing height, eye and shoulder heights (standing), and knee height (sitting) shall be increased by 1.0 inch by the addition of shoes.*(2)

3. The dimensions shown on Figure 5-3 shall be employed for design purposes where suited/pressurized transit or access is either required or anticipated.*(2)

4. The crew shall be selected and trained to perform tasks requiring a mixture of skills as determined by mission requirements and functional analysis.*(2a)

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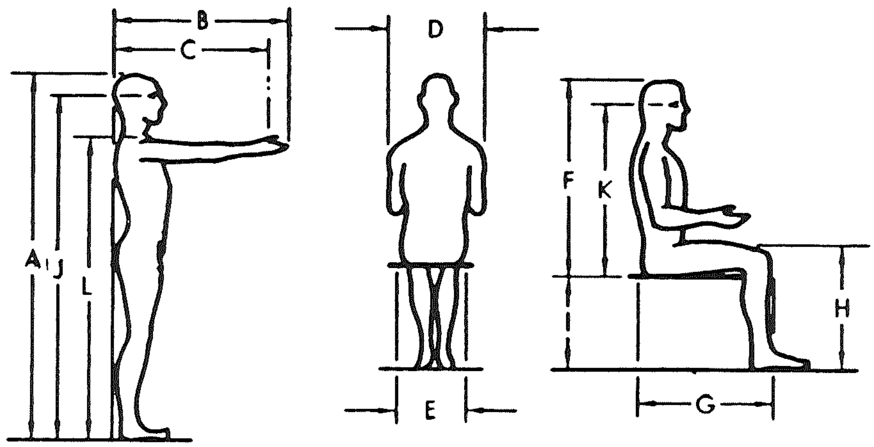
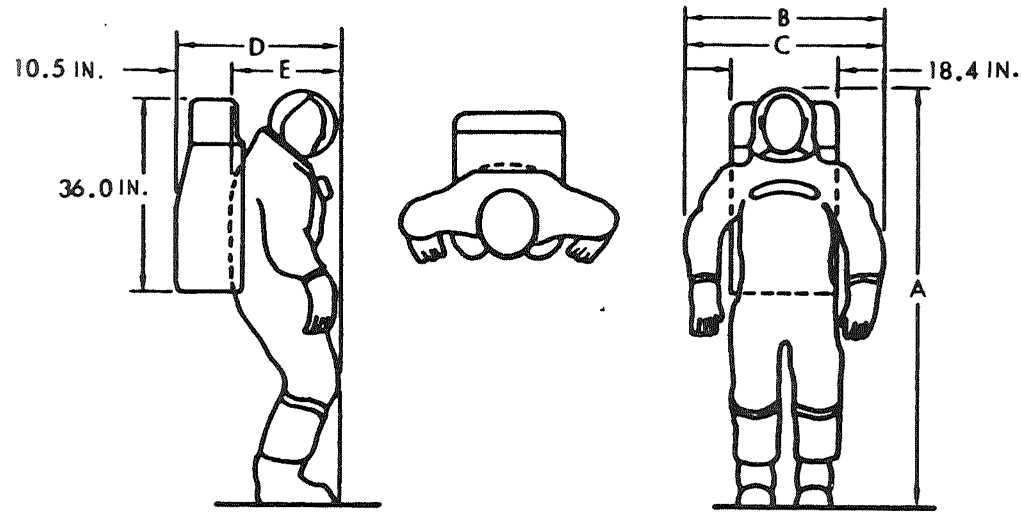
*Refer to specified item number in Section 5.5



DIMENSION	PERCENTILE (INCHES)	
	5th	95th
A - STANDING HEIGHT	65.8	73.8
B - MAXIMUM REACH	32.4	38.3
C - FUNCTIONAL REACH	29.0	34.2
D - SHOULDER BREADTH	17.3	20.7
E - HIP BREADTH (SITTING)	13.4	16.4
F - SITTING HEIGHT	34.7	38.8
G - BUTTOCK-KNEE LENGTH	22.0	25.5
H - KNEE HEIGHT (SITTING)	20.3	23.6
I - POPLITEAL HEIGHT	15.9	18.5
J - EYE HEIGHT (STANDING)	61.1	68.8
K - EYE HEIGHT (SITTING)	29.9	33.9
L - SHOULDER HEIGHT	53.1	60.8
WEIGHT (LBS)	140.1	210.7

Figure 5-2. Pertinent Crewman Dimensions



DIMENSION	PERCENTILE (INCHES)	
	5th	95th
A - HEIGHT	68.1	76.3
B - MAX BREADTH AT ELBOWS (ARMS RELAXED)	27.2	30.7
C - MAX BREADTH AT ELBOWS (ARMS AT SIDE)	26.0	27.3
D - MAX DEPTH WITH PORTABLE LIFE SUPPORT SYSTEM (PLSS) & BACKUP OXYGEN (OPS)	27.0	29.4
E - MAX DEPTH WITHOUT PLSS/OPS	15.5	17.9
WEIGHT (LBS), WITH PLSS/OPS	323.6	395.2
WEIGHT (LBS), WITHOUT PLSS/OPS	197.9	286.5

NOTES:

FOR DIMENSIONS D AND E, 2" HAVE BEEN ADDED TO MAXIMUM CHEST DEPTH OF SUITED/PRESSURIZED CREWMAN FOR PLSS CONTROL BOX, TO OBTAIN ENVELOPE DIMENSIONS.
MEASUREMENTS MADE ON A7L PGA, PRESSURIZED TO 3.75 PSIG.

Figure 5-3. Suited/Pressurized Crewman Envelope Dimensions

5.2.2 Crew Personal Equipment

Crew Apparel *(3)

Crew apparel shall include those garments customarily worn by the crew in a shirtsleeve mode of operation. They shall provide for general comfort, warmth, and perspiration absorption. Articles of clothing required and the usage rates shall be in accordance with the following:

Item	Usage Rates (Days)	
	Nominal	Maximum
Shirt (short-sleeve)	4	16
Trousers	7	14
Jacket (lightweight)		Tour of duty
Undershirt	2	3
Undershorts	2	3
Socks (pair)	2	3
Shoes (pair)		Tour of duty
Overalls	1	3

Crew Linens *(3)

Item	Usage Rates (Days)	
	Nominal	Maximum
Sheets	7	10
Blanket	(Not Applicable)	
Towels	7	7
Washcloths	2	7

Crew Personal Effects

Crew personal effects shall include toilet articles, grooming equipment, cleansers, and items of personal equipment of the individual crewman's choice. *(3)

*Refer to specified item number in Section 5.5

Miscellaneous Personal Equipment

Personal radiation dosimeters shall be provided for each crewman. They shall be worn at all times (in pockets on crew garments) and shall be capable of measuring accumulated radiation dosage.*(5)

5.2.3 General Crew Equipment

Crew Mobility Aids

Crew mobility aids in the form of handholds, guide rails and other devices shall be provided to facilitate crew locomotion, stabilization/bracing, and transit in zero-g environment. They shall be capable of use in either a shirtsleeve or suited/pressurized mode of operation. Handholds and guide rails shall be a minimum of 1.0 inch in diameter with a 2.0-inch clearance to adjoining structure or surface to permit use with a gloved hand (suited/pressurized operations).*(8)

Crew Restraint Devices

Crew restraint devices, such as tethers/tether attach fittings, harnesses, belts and straps, various foot restraining devices, and articulated or extensible mechanical devices shall be provided for bracing and stabilization or preventing inadvertent drift of a crewman, in the zero-g environment. For a shirtsleeve mode of operation, a suitable device shall be provided for each bunk and chair-seating device and for each crew work station and personal activity function to maintain a relatively fixed relationship of the crewman with respect to the work station or personal activity equipment. Suitable devices compatible with the PGA, shall be provided for a suited/pressurized mode of operation. Crew restraint devices shall be relegated to the lower body, legs, and feet to permit freedom of movement of the upper torso, arms, and hands.*(8)

Equipment Restraint Devices

Restraint devices shall be provided for retention of all items of loose equipment (e.g., equipment not stowed in storage facilities). A positive retention/restraint method, such as tethers or detachable mechanical devices, shall be required for large items of equipment during crew handling (e.g., cargo and equipment transfer).*(8)

Cargo Handling and Transport Provisions

A mechanized transport system shall be provided for movement of heavy cargo, equipment, sensitive or special and personnel.*(8b)

Tools

Standard tools shall be provided for calibration, maintenance and repair of the various subsystems, experiment equipment items, and other LEP elements.*(8b)

*Refer to specified item number in Section 5.5

Radiation Monitoring Devices

In addition to the personal radiation dosimeters provided as personal equipment and worn by the crewmen, suitable devices shall be provided at selected locations within the space station to measure ambient radiation levels as well as cumulative radiation dosage.*(10)

5.2.4 Crew Furnishings

For crew furnishings requirements see Tables 5-1 and 5-2.*(11)

5.2.5 Recreation

Equipment shall be provided for crew recreational purposes and off-duty crew relaxation for the shirtsleeve and zero-g environments.*(12)

Passive entertainment activities shall be provided in the form of music (e.g., intercom, tape deck), television (either transmitted from moon, ground or video tape), and movies (projector and stowable motion picture screen).

At least two observation windows shall be provided for recreational earth, moon and/or celestial viewing. A captive-type light-tight cover shall be provided to close off the windows when desired.

5.2.6 Exercise

Equipment shall be provided to accommodate crew physical conditioning requirements in a shirtsleeve zero-g environment.*(13)

5.2.7 Medical Care

Equipment shall be provided for medical and dental care of the crew and shall be capable of operation in a shirtsleeve zero-g environment. The type of measurements required to be made by the OLS medical facility are listed in Table 5-3.*(13)

To provide the medical support required for OLS, the medical area must have one each of the following facility capabilities:

Examination table
Sterilizer
Refrigerator/freezer
Field type x-ray
Sink, lavatory
Work surface
Set of medical diagnostic equipment

*Refer to specified item number in Section 5.5

Table 5-1. Crew Furnishings Requirements

Item	Staterooms			Galleys		Dining Area	Recreation	Medical Area
	Crew	Cmdr	Tug Cmdr	Primary	Backup			
Sleeping restraint/bunk								
Fixed	6	1	1					
Auxiliary	6	1	1					
Seating restraint/chair	6	2	2			4	4	1
Work surface/table/desk								
Fixed	6	1	1	1	1	1	1	1
Auxiliary				1				1

Table 5-2. Crew Furnishings Dimensional Criteria (Inches) *(8)

Item	Width		Depth/Length		Height	
	Min	Pref	Min	Pref	Min	Max
Sleeping restraints/bunks:						
Primary	30		78			
Auxiliary	28		76			
Seating restraints/chairs(*)	16	18	16	18	17	18
Work Surfaces/tables/desks:						
General staterooms	30	36	18	24	28	30
Commander's stateroom	36	42	24	30	28	30
Tug Cmdr stateroom	36	42	24	30	28	30
Primary galley:						
Fixed	42		24		36	40
Auxiliary	36		18		36	40
Backup galley:						
Fixed	18		12		36	40
Dining area	30	32	48	54	28	30
Recreation area	30	32	30	32	28	30
Exercise area	(None required)					
Fixed medical treatment area	30	42	24	30	28	30
Auxiliary medical treatment area	30		18		36	40
Knee space (for work surfaces/ tables/desks)	22	24	20	22	25	26
(*) Seat back to seating surface angle - 95 to 105 degrees						

5.3 OPERABILITY

5.3.1 Reliability

See Section 2.2.

*Refer to specified item number in Section 5.5

Table 5-3. Measurements List for the OLS Medical Facility

Group	Type	Tests
I	Clinical evaluation	History Physical examination
II	Cardiovascular	Electrocardiogram Vectorcardiogram Cardiac output Arterial blood pressure Venous pressure Phonocardiogram Heart rate
III	Respiratory	Lung volumes Timed vital capacities Airway resistance Total airway compliance Diffusion capacity
IV	Metabolism	Energy metabolism Balance studies Body mass Temperatures (core and skin)
V	Clinical laboratory	Complete blood count Urinanlysis Plasma volume Electrolytes (blood and urine) Total protein Blood glucose Blood pH; pO_2; pCO_2 Reticulocyte counte Red blood cell fragility Red blood cell mass and survival
VI	Behavioral effects	Vision test Audiometric test

5.3.2 Maintainability*(8)

See Section 2.2.

*Refer to specified item number in Section 5.5

5.3.3 Useful Life

See Section 2.2.

5.3.4 Environments

See Section 2.2.

5.3.5 Human Performance

See Section 2.2.

5.3.6 Safety Provisions

1. Provisions shall be made for the protection and survival of the full complement of personnel at an emergency level during solar storm activity consistent with the radiation allowables and with the specified radiation environmental model and duration for solar storms.*(8f)

2. Provision shall be made for emergency medical treatment of sick or injured crewmen. For those sick or injured crewmen that require medical treatment beyond the OLS onboard capability, further provisions must be made. This includes care and stabilization of the patient until medical aid can be brought in, or the patient can be returned to earth. The minimum period for which injured crewman must be stabilized awaiting medical aid is 120 hours.*(14)

3. Provisions shall be made for the restraint of irrational personnel.

4. Provisions for suited IVA, EVA, and entry into hazardous areas shall be based on the operation being conducted by at least two men. Provisions shall be made for the rescue of one man by the other in an emergency.*(8f)

5. Provisions shall be made for containing (e.g., confining) emergencies such as fires, toxic contamination, depressurization, structural damage, etc.*(8f)

6. Provisions shall be made for emergency treatment of injured personnel following an accident that renders unavilable the pressurizable volume containing the primary medical facilities.*(13)

7. Pressure suits, backpacks and umbilicals, and related support equipment shall be provided in readily available locations so that two suits may be reached and donned from any location in the OLS with any one pressurizable volume being inaccessible due to an accident.*(8f)

*Refer to specified item number in Section 5.5

5.4 MAJOR INTERFACES

5.4.1 Experiment Provisions

1. Crew support for experiment operations equivalent to five men working one 10-hour shift per day shall be provided.*(6, 8)

2. The crew skill mix shall be as identified in the Experiment Operating Plan. The OLS crew required for experiment operations shall have the skills necessary to activate, operate, maintain, record, and analyze data, and deactivate the on-board experiments for each scientific discipline represented.

5.4.2 Structures

General

The OLS interior shall be designed in accordance with good architectural and decorator practices in order to provide comfortable, efficient, and attractive living and working spaces. The interior arrangement shall insure crew comfort, efficiency, and physiological and psychological well-being. The arrangement of all equipment within a given area shall be in an upright (earth-like) orientation.*(8)

The OLS interior shall be partitioned into basic functional areas including the following: *(8)

Individual crew staterooms
Food preparation, preservation and serving areas
Dining area
Recreation area
Personal hygiene areas
Exercise area
Medical treatment area
Work areas
Storage areas
Aisles, passageways, and tunnels

Mounting provisions shall be provided throughout the OLS for mobility aids and restraints, including handhold, guide rails, footholds, and/or tethers required for crew locomotion and/or bracing/stabilization. Design features which should be considered include: *(8)

Spacing of mobility aids shall be such that either these devices, vehicle structure, or equipment/accommodations shall always be within reach of a crewman.

*Refer to specified item number in Section 5.5

Mobility aids shall be mounted on equipment or accommodations where appropriate as well as on vehicle structure.

Design of vehicle structure equipment and accommodations shall consider features which inherently provide a mobility aid capability.

Handholds shall be either the rigid, flexible or recessed type, as appropriate to a specific location.

Guide rails shall be located between 36 inches and 40 inches above the floor and shall be provided on both sides of aisles and passageways.

Handholds shall be appropriately located with respect to crew mobility requirements.

A continuous guide rail shall be provided for crew interdeck transit. The cargo transport device may provide the capability for this purpose.

Where ladders are provided for interdeck transit, the clearance behind ladders to a surface or bulkhead shall be no less than 6 inches, and the climbing space in front of ladders shall be a minimum of 32 inches wide by 32 inches deep.

The wall-to-wall area requirements are included in Table 5-4.

Table 5-4. Wall-to-Wall Area Requirements*(8)
(8-Man)

Area	Square Feet
Staterooms - General	400.0
Galley - Primary	56.0
- Backup	40.0
Dining	44.0
Recreation	80.0
Exercise	60.0
Medical	144.0
Personal Hygiene - Primary	96.0
- Backup	96.0
Laundry	35.0
Total	1051.0

*Refer to specified item number in Section 5.5

All equipment installed within the OLS shall be such that access to the pressure hull can be readily achieved for inspection and/or repair. The access provisions shall be such that a suited/pressurized crewman can gain access to the pressure hull (equivalent of a minimum 32 inches by 78 inches accessway.*(8) The access requirements are listed in Table 5-5.

Table 5-5. Access Requirements (Hatchways/Doors)*(8)

Functional Area	Height (Inches)		Width (Inches)	
	Minimum	Preferred	Minimum	Preferred
General crew staterooms	78	82	28	30 - 32
Commanders stateroom	78	82	28	30 - 32
Tug commanders stateroom	78	82	28	30 - 32
Primary galley	78	82	32	36 - 42
Backup galley	78	82	32	36 - 42
Dining area	78	82	32	-
Recreation area	78	82	32	-
Personal hygiene area	78	82	32	36
Crew exercise area	78	82	32	-
Medical treatment area	78	82	32	36 - 42
Crew work station	78	82	28	30 - 36

Provisions shall be made for illumination as shown in Table 5-6.

Crew Accommodations

There shall be eight individual crew staterooms designed for single occupancy during routine operations and dual occupancy during periods of crew overlap or emergencies. Occupancy during routine operations shall be considered to be 180 days, dual occupancy during overlap for periods up to 16 days, and dual occupancy during OLS emergencies for periods up to 30 days. *(15)

*Refer to specified item number in Section 5.5

Table 5-6. OLS Lighting Requirements (Foot-Candles)*(8)

Area	Overhead (1)	Supplementary Local (2)	Emergency (1)	Low Level (1)
Crew staterooms (6)	30	Desk 50 Bunk 50	5	0.5
Commanders and exp. Coordinator staterooms (2)	30	Desk 50 Bunk 50 Grooming 50	5	0.5
Primary galley	50	Work counter 50-70	5	0.5
Backup galley	10	Work counter 30	5	0.5
Primary dining	variable to 30 (3)	Eating surface 30-50	5	0.5
Recreation	variable to 30 (3)	30-50	5	0.5
Personal hygiene			5	0.5
Lavatories	30	50	5	0.5
Toilets	30		5	0.5
Showers	30		5	0.5
Exercise	30	-	5	0.5
Medical	Selectable 50 and 150	Work counter 50-70	100 diffused 500 (4)	0.5
Work stations				
Maintenance/repair	30-50	Work counters 50-70	10	0.5
Experiment	30-50	Work counters 50-70	10	0.5
Control centers	variable 5-50		10	0.5
Airlocks	30		5	0.5
Aisles, passageways Tunnels-direct diffused	30			0.5

(1) Foot-candles are measured 30 inches above deck.
(2) Unless specified, intensities are measured at the surface of use.
(3) Variable lighting to 30 foot-candles may be designed with 0.5 foot-candle low limit to provide night light.
(4) Auxiliary diffused illumination of 500 foot-candles will be provided, automatically actuated in event of power failure.
(5) Diffused 500- to 1000-foot-candle lamp shall be located above the examination chair and be directionally adjustable in medical and dental area.
(6) Low-level lighting shall always be on except when emergency lighting is in use.

*Refer to specified item number in Section 5.5

For emergency case involving rescue of crew from another lunar exploration program system (i.e., LSB or RNS in lunar orbit), the OLS must provide support to a total of 20 men for 55 days with additional crew support capability available from two docked tugs.*(1)

The staterooms shall be divided equally between two separate pressure volumes with the commander's and tug commander's staterooms in different volumes.*(16)

Galley Requirements*(16)

1. Provisions shall be made for a galley which is capable of providing the nutritional needs of the 8-man crew.

2. The galley shall be capable of being occupied by up to two crewmen simultaneously during periods of food preparation. The galley shall be capable of serving a minimum of four crewmen simultaneously.

3. A backup galley shall be provided which is capable of satisfying the nutritional needs of the 8-man crew for a period of at least 30 days.*(17)

4. The backup galley shall be in the opposite pressure volume from the primary galley.

5. The backup galley shall be capable of preparing and serving only dried (rehydratable), thermostabilized (canned), or other types of packaged food not requiring special preparation equipment or refrigeration or other preservation techniques.*(17)

Dining Area Requirements*(17)

1. One dining area shall be provided which is capable of accommodating up to four crewmen simultaneously during periods of routine operations.

2. OLS crewman shall utilize staterooms, aisles, or other available space as backup for the dining area.*(16)

Recreation Area Requirements*(17)

1. A recreation area shall be provided which shall be utilized by the crew for relaxation and entertainment during off-duty hours.

2. The recreation area shall be located adjacent to the primary dining area.

---

*Refer to specified item number in Section 5.5

3. The recreation area shall be capable of accommodating up to four crewmen simultaneously during periods of routine operations. The area shall be used in conjunction with the dining area to provide accommodations for up to 8 men for purposes other than recreation such as meetings.

Personal Hygiene Requirements*(17)

1. The personal hygiene facilities shall be divided equally between the two pressure volumes and shall be located on the same decks as the individual crew staterooms.

2. Equipment shall be arranged to maximize personal privacy and to minimize interference between crewmen using adjacent equipment. Screens/doors shall be provided in front of the toilets and shower dressing areas for personal privacy.

Crew Exercise Area Requirement

A crew exercise area shall be provided for crew conditioning and physical fitness and be located adjacent to or as a part of the medical area.*(13)

Medical Treatment Area Requirements

One medical treatment area for routine crew monitoring shall be provided. The medical treatment area shall also be capable of supporting the diagnosis and treatment of crew injuries and illnesses.*(13)

Intervolume Airlock Requirements*(16)

1. An intervolume airlock capable of accommodating two crewmen simultaneously shall be provided between pressure volumes.

2. The airlock shall have a minimum height of 84 inches and a minimum diameter of 60 inches for a cylindrical airlock or equivalent.

3. Outward opening hatches and associated actuating mechanisms for access to and egress from each pressure volume shall be provided.

Requirements for Aisles, Passageways, and Tunnels*(8)

1. Aisles, passageways, or tunnels shall be provided wherever crew, cargo, or equipment transfer is required.

*Refer to specified item number in Section 5.5

2. Aisles and passageways for crew transfer only shall have a minimum width of 32 inches with 36 inches to 42 inches preferred. The height shall be a minimum of 82 inches with 86 inches preferred. A height of 84 inches shall be considered as nominal.

3. Tunnels for crew transfer only, which are less than seven feet in length, shall have a minimum diameter of 42 inches; tunnels which are greater than seven feet shall have a minimum diameter of 48 inches.

Acoustic Noise Limitations*(8)

1. Acoustic noise levels shall be maintained such that no adverse psychophysiological effects will be produced.

2. Noise levels shall not cause discomfort to crewmen nor interfere with communication between crewmen at normal voice levels up to distances of 18 feet.

3. Continuous noise levels shall not exceed 50 decibels in the speech interference level (SIL) range (600 to 4800 Hertz), 70 decibels at frequencies below SIL, nor 60 decibels at frequencies above SIL.

4. The maximum acoustic noise levels for various frequencies, in relation to OLS functional areas shall be in accordance with the values specified in Figure 5-4.

Vibration Limitations*(8)

1. Vibration emitting equipment shall not be located in crew living areas, and where required in crew work areas, shall be shock-mounted, insulated, or otherwise dampened so as not to adversely affect crew performance.

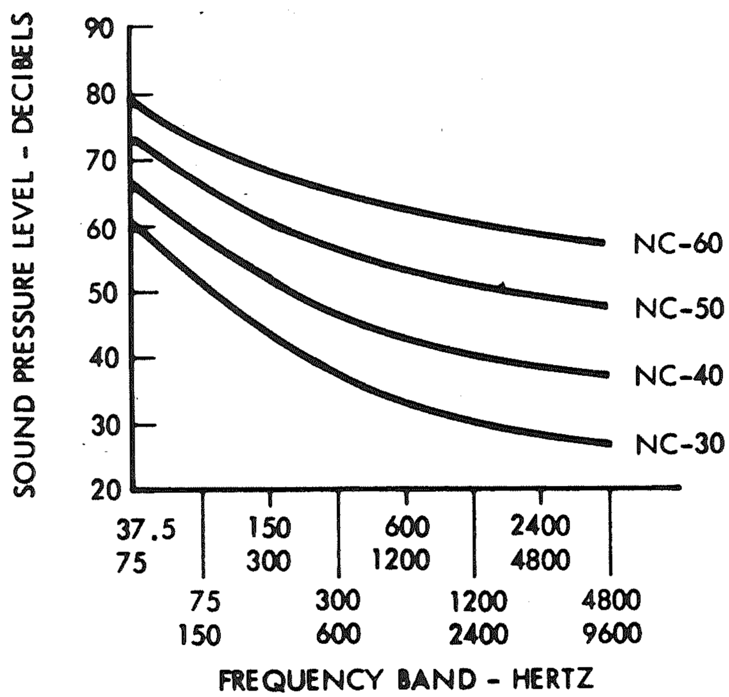
2. Where necessary, seating and restraining devices shall incorporate provisions to absorb perceptible vibrations.

5.4.3 Environmental Protection Subsystem

1. Provide thermal and meteoroid protection.

2. Provide radiation protection.*(8f)

*Refer to specified item number in Section 5.5



NC CURVE	APPLICATION
NC-30	SLEEP/REST AREAS
NC-40	CONTROL AREAS WHERE COMMUNICATIONS ARE CRITICAL: AREAS WHERE SOME CONCENTRATION AND RELAXED COMMUNICATION MAY BE DESIRABLE (RADIO AND TELEVISION LISTENING)
NC-50	AREAS WHERE GOOD COMMUNICATION CONDITIONS ARE NOT ESSENTIAL (SOME DISTRACTION TO EXTERNAL NOISE CAN BE PERMITTED); INTERNAL NOISE GENERATION DUE TO OTHER ACTIVITIES MAY BE PRESENT; GENERAL WORK/LIVING AREAS
NC-60	MAINTENANCE AREAS

Figure 5-4. Maximum Acceptable Acoustical Noise Levels

Radiation protection shall be provided to limit crew radiation dosage as specified below (all doses in rem).

Depth/Period	Career	Year	30 Days
Skin (0.1 mm)	2400	240	150
Eye (3 mm)	1200	120	75
Marrow (5 cm)	400	40*	25

*This limit may be doubled if the crewman is not exposed to any further radiation for the succeeding 12 months following the one year counted for exposure (e.g., no more than 80 rem in a 24-month period).

The rate limit for radiation from all artificial sources shall not exceed 0.15 rem/day.

5.4.4 Electrical Power Subsystem

1. Electrical power shall be provided for general, supplementary, and emergency illumination for the areas shown in Table 5-6.*(16)

2. Electrical power shall be provided for one color television set in each crew stateroom.*(16)

3. Electrical power shall be provided for the crew-related recreation and entertainment equipment in the recreation area. The equipment and associated power requirements are as follows: *(16)

Item	Power (watts)
Movie projector	500
Color television	300
Tape deck	50

4. The following electrical power shall be provided for each PGA: *(18)

   a. 56 vdc - 2 amperes at the umbilical interface when the suit is in operation

   b. 250 watt-hours for battery charging of each PGA

*Refer to specified item number in Section 5.5

5. Electrical power shall be provided for the field type X-ray in the medical treatment area. This shall require an average of 200 watts for operation.

6. The capability and electrical power shall be provided for recharging the portable lights.*(19)

5.4.5 Environmental Control/Life Support Subsystem

Atmosphere*(8)

The cabin atmosphere shall consist of an oxygen/nitrogen mixture at a normal operating pressure of 14.7 psia but capable of operating at selected pressures between 10 psia and 14.7 psia. The atmospheric total pressure so provided will maintain the partial pressure of oxygen in the alveolar spaces of the lungs between the limits of 100 mm Hg to 120 mm Hg. The various oxygen/nitrogen mixtures necessary to provide a partial pressure of oxygen of 3.08 psi and an alveolar partial pressure of oxygen of 100 mm Hg for cabin atmospheres ranging from 14.7 to 10.0 psia are as follows:

Oxygen (Percent)	Nitrogen (Percent)	Cabin Pressure (psia)
20.9	79.1	14.7
21	79	14.65
22	78	14.0
23	77	13.4
24	76	12.8
25	75	12.3
26	74	11.8
27	73	11.4
28	72	11.0
29	71	10.6
30	70	10.25
30.9	69.1	10.0

*Refer to specified item number in Section 5.5

Carbon dioxide tensions on the OLS shall be maintained below 7.6 mm Hg in all habitable areas. The atmosphere constituents, including harmful air-borne trace contaminants, shall be identified, monitored, and controlled in each pressurized compartment of the OLS.

In the event of OLS pressure hull damage resulting in pressure decay in a pressure volume. the duration of acceptable crew performance shall be considered to be that period of time until a partial pressure of oxygen of 1.9 psi is reached.

Facilities shall be provided for prebreathing 100 percent oxygen, for preconditioning a crewman prior to IVA/EVA operations.

Temperature*(8)

The capability shall be provided to maintain the temperature nominally between 65 F and 75 F in habitable regions of the OLS. Selective (independent) temperature control, on an area basis, shall be provided.

The temperature of interior exposed surfaces with which a crewman may come in contact shall not be less than 57 F for both metallic and nonmetallic surfaces nor more than 105 F for both metallic and nonmetallic surfaces.

Humidity*(8)

The water vapor partial pressure shall be maintained between 8 to 12 mm Hg, and no condensation shall form on internal surfaces.

Air Velocity*(8)

Air velocity shall be maintained between 15 feet per minute and 100 feet per minute, with 40 feet per minute as the nominal ventilation flowrate. The capability shall be provided to adjust the flowrate for crew comfort.

Auxiliary ventilation for localized cooling and comfort shall be provided, with both ventilation flowrate adjustment and selectable directional flow for certain areas.

Odor Control*(8)

Provisions for odor control shall be provided within each pressurized compartment of the OLS.

Contamination Control*(8, 13)

Microbiologically and bacteriologically contaminated waste material shall be disinfected as close as possible to its source prior to storage, processing or disposal.

*Refer to specified item number in Section 5.5

The concentration of bacteria within the atmosphere and within each of the pressurized compartments containing crew quarters, process laboratories, or experimental facilities shall be monitored and controlled by appropriate means.

Metabolic Criteria*(8d)

The following specify metabolic criteria for light activity in a shirt-sleeve, 14.7 psia (20.9 percent oxygen, 79.1 percent nitrogen) environment and shall be used for design purposes:

Metabolic load (nominal) - 11,900 Btu/man/day, equivalent to 3000 kcal/man/day

Oxygen consumption (nominal) - 1.84 lb/man/day

Carbon dioxide production (nominal) - 2.25 lb/man/day

Water balance (nominal) - 7.10 lb/man/day

Average metabolic rates for various activities are as follows:

Sleeping	280 Btu/hr
Eating	450 Btu/hr
Working (light activity)	600 Btu/hr
Exercise (moderate to heavy)	1600 Btu/hr
Recreation (relaxation)	400 Btu/hr
Personal hygiene activities	465 Btu/hr
EVA/IVA (suited/pressurized)	1200 Btu/hr

Water Management*(8d, 13)

Sufficient potable water shall be provided for the crew to maintain water balance. Potable water requirements in pounds per man per day, based on a metabolic load of 11,900 Btu per man per day, are included in Table 5-7.

Sufficient water shall be provided for washing and cleaning to satisfy the following requirements:

Crew washwater - 4.0 pounds/man/day

*Refer to specified item number in Section 5.5

Table 5-7. Potable Water Requirements

	Cabin Pressure	
	14.7 psia	10.0 psia
Water		
Water of oxidation (from food)	0.78	0.78
Beverages plus water in food	6.32	6.47
Totals	7.10	7.25
Water loss		
Insensible (lungs + latent)	2.44	2.69
Sensible (perspiration)	1.06	0.96
Urine	3.45	3.45
Water in feces	0.15	0.15
Totals	7.10	7.25

Crew shower water (based on two showers/man/week at 17.2 pounds of water/shower) - 4.9 pounds/man/day

Dishwashing/housekeeping - 3.0 pounds/man/day

Laundry - 4.0 pounds/man/day

Hot water (155 degrees F +/- 5 degrees F) and cold water (50 degrees F +/- 5 degrees F) shall be provided in sufficient quantities for crew usage in both personal hygiene areas and food preparation areas.

The capability shall be provided for mixing hot and cold water in a suitable ratio so as to provide water at a temperature comfortable for crew washing and showering.

Food Management*(7)

Food shall be provided for crew consumption in accordance with the following requirements.

*Refer to specified item number in Section 5.5

1. Daily caloric requirements shall be as follows:

   Normal diet - 3000 kcal per man

   Contingency diet (short duration) - 2000 kcal per man (minimum)

2. The food management equipment shall provide the following types of food in the approximate proportions specified:

Dried and freeze-dried (rehydratable)	45 percent
Frozen	30 percent
Thermostabilized (canned)	20 percent
Fresh	5 percent

3. The food supply characteristics shall be as follows:

Total food supply (dry)	1.68 lb/man-day
Dried foods (all types)	1.04 lb/man-day
Dry portion of wet foods (frozen, canned, fresh)	0.64 lb/man-day
Food not ingested	0.18 lb/man-day
Water in wet foods	0.96 lb/man-day
Packaging material:	
Dried foods	0.73 lb/man-day
Wet foods	0.45 lb/man-day

4. Individual and bulk food packaging and preparation capability shall be provided.

The equipment necessary to prepare, preserve, and serve the food required to satisfy the crew nutritional needs shall be provided.*(8)

EVA/IVA Pressure Garment Assemblies

A total of four pressure garment assemblies (PGA) and their support equipment shall be provided. Two PGA's and their support equipment shall be provided in each pressure volume of the OLS.*(6a)

*Refer to specified item number in Section 5.5

Each PGA shall provide a mobile life support chamber for a crewman and shall contain a 100-percent oxygen environment at an operating pressure of 3.75 +/- 0.25 psia. The PGA environment shall be supplied by either of the following, depending upon the mode of operation:

1. EVA - a self-contained portable life support system (PLSS) with an attached oxygen purge system (OPS) (emergency oxygen supply).

2. IVA - through an umbilical system from the OLS ECLSS, connecting to a pressure control unit (PCU) worn on the PGA. The capability to use the PLSS/OPS for IVA operations also shall be provided.

When an umbilical system is utilized, these umbilicals shall supply oxygen and liquid cooling capability and shall provide for two-way voice communications, transmission of bioinstrumentation signals from the crewman, and transmission of electrical power and caution/warning signals to the crewman. Umbilicals for IVA usage shall be provided as follows:*(6b)

1. Two sets of short umbilicals emanating from the intervolume airlock of sufficient length to permit two suited/pressurized crewmen to reach storage locations of long umbilicals.

2. Two sets of long umbilicals shall be provided in each pressure volume emanating from a central location and of sufficient length to permit two suited/pressurized crewmen to reach any location in either pressurized volume.

In addition to the PLSS/OPS or umbilicals/PCU for life support, the following equipment shall be required for use with each PGA: (eight of each item shall be provided, on the basis of two per pressure volume and four shall be provided for scientific exploration).*(6a)

1. Liquid cooling garment (LCG) shall be worn as an undergarment for the PGA to provide for general comfort, perspiration absorption, and thermal transfer between the crewman's body and the garment's cooling media.

2. Fecal containment equipment (FCE) shall be worn as an undergarment for the LCG to permit defecation during a suited mode.

3. Urine collection and transfer equipment (UCTE) shall be worn over the LCG while a crewman is in the PGA to provide for the collection and intermediate storage of urine. Subsequent transfer of urine from the UCTE to the OLS waste management assembly shall be required, utilizing a UCTE clamp and a UCTE transfer adapter.

*Refer to specified item number in Section 5.5

4. Bioinstrumentation assembly shall be worn with the LCG to provide the capability for physiological monitoring of a crewman.

5. Personal communications equipment shall be worn with the PGA to provide dual earphones and dual microphones for crew voice communications capability.

6. Extravehicular (EV) gloves shall be worn for EVA in lieu of the intravehicular (IV) gloves normally provided for the PGA.

Life support expendables shall be provided for EVA/IVA as follows:

There are no scheduled EVA/IVA. Unscheduled EVA/IVA would occur for emergency repair or maintenance of experiments or disabled pressure volume. In the case of cabin puncture due to meteoroid penetration, IVA for 2 men for 4 hours is required.

Emergency General Crew Equipment

Emergency general crew equipment shall consist of portable lights and a medical accessories (first aid) kit. They shall satisfy the following performance requirements.

Portable Lights. A total of four portable lights shall be provided for emergency maintenance or inspection in the event of power failure. Each portable light shall be capable of providing floodlight-type direct illumination of 100 foot-candles at a distance of 10 feet and not less than 50 foot-candles at this same distance after 3 hours of continuous operation. Each portable light shall have a carrying handle and actuation device compatible for use with a gloved hand (suited/pressurized operations).*(9)

Medical Accessories Kit. A medical accessories (first aid) kit shall be provided. This kit shall be capable of providing for medical emergencies when the pressure volume in which the medical treatment area is located is untenable. This kit shall include such items as oral drugs, injectable drugs, dressings, bandages, and topical agents.*(9)

Emergency Personal Equipment

Emergency personal equipment shall consist of an emergency full face oxygen mask, which shall provide for emergency breathing in the event of smoke or toxic gases. Sixteen oxygen masks shall be provided in strategic places of the OLS. An integral oxygen bottle on each mask shall provide a minimum 5-minute oxygen supply.*(4)

*Refer to specified item number in Section 5.5

5.4.6 Information Subsystem

Alarms and Displays*(8)

Audio and visual alarms shall be provided in all habitable areas. The audio alarms shall be both tone and voice with the voice alarm defining the crew action to be taken (e.g., preprogrammed crew actions). The visual alarms shall be of the flashing light type and shall be used primarily to alert the crew to the presence of a dangerous or potentially dangerous situation.

Communications Requirements*(8)

Two-way intercommunications shall be provied.

Two-way hardline and RF communications shall be provided between the primary or backup control stations and crewmen performing IVA/EVA in pressure suits.

The capability for private communications with the ground shall be provided.

The capability to receive selectable entertainment type audio and video communications (music and television) shall be provided.

The capability to broadcast (time-delayed) selectable earth radio and television programs shall be provided.

5.5 RATIONALE

1. Crew. Refer to Section 5 of Volume 2 for rationale for requirement to support 20 men for 55 days in event of LSB failure.

2. Crew. The anthropormorphic data given was taken from a letter from the Department of the Air Force, Charles E. Caluser, Chief, Antropology Branch, Human Engineering Division, 6570th Aerospace Medical Research Laboratory, WPAFB, Ohio 45433, Summary Data 1967 Survey, dated 13 March 1970. The original EOSS data was based on the 1950 AF survey taken from AF Report No. WADC-TR-52-321 and NR Sketch No. SKA 0016 A7L Pressure Garment Assy Dimensions, dated 19 October 1967.

   a. Crew selection and training for OLS operations has as its prime purpose that of providing the required crew skills with the least number of crewmen possible and yet adequately support OLS mission objectives.

*Refer to specified item number in Section 5.5

3. Crew usage rates are based on common usage under normal earthside conditions.

4. Emergency Personal Equipment. Sixteen emergency oxygen masks have been provided to have at least one mask for each crewman onboard to support the crew overlap period during crew rotation which can extend up to 16 days before the RNS returns to earth orbit.

5. Based on Apollo requirements.

6. EVA/IVA Pressure Garment Assemblies:

   a. Four PGA's are used for lunar surface work and can be considered as part of the scientific equipment payload. The remaining four PGA's provide backup in the event of pressure loss in either station pressure volume and also provide the capability for external station maintenance. Also, two of these four suits would provide the PGA's for the OLS flight crew performing a tug rescue of the lunar surface sortie crew.

   b. For purposes of IVA within a disabled station pressure volume, only two sets of short umbilicals and two sets of long umbilicals are provided. This quantity provides the minimum to fulfill the safety requirement that every EVA/IVA operation must have a safety backup man who can rescue the working crewmen in case of accident.

7. Based on EOSS zero-g shirtsleeve operations for an energy output of 11,900 Btu/man/day, Apollo data and data from the Compendium of Human Responses to the Aerospace Environment, NASA CR-1205, Volume III, November 1968.

8. Based on one or more of the following documents covering human engineering criteria:

   a. McCormick, E. J., Human Engineering, McGraw-Hill Book Co., Inc., New York (1957).

   b. Morgan, C. T., et al, Human Engineering Guide to Equipment Design, McGraw-Hill Book Co., Inc., New York (1963).

   c. Standard-Human Engineering Design Criteria, MSFC-STD-267A (23 September 1966).

   d. Compendium of Human Responses to the Aerospace Environment, NASA CR-1205 (November 1968).

   e. Bio-Astronautics Data Book, NASA SP-3006 (1964).

f. Guidelines and Constraints Document, EOSS Program Definition, Phase B, MSC-00141, Space Station Task Group, Advanced Missions Program Office, MSC, Houston, Texas.

9. One portable light per deck should be adequate for emergency use of portable lights based on EOSS requirements and the probable number of emergencies that may be expected. This is based on EOSS requirements and a safety factor of having a limited medical capability in either pressure volume.

10. Based on Apollo requirements and the EOSS Guidelines and Constraints document (see item 8f above).

11. Based on presently accepted OLS crew size. See item 1.

12. Based on EOSS developed requirements, 8d above, and The Intangibles of Habitability During Long Duration Space Missions, T. M. Fraser, Report No. NASA CR-1084 (June 1968).

13. Based on NASA's medical program as at least partially reported in the following documents:

    a. Berry, C. A., et al, Apollo 7 to 11 Medical Conserns and Results, NASA Memo TMX-58034 (November 1969).

    b. Berry, C. A., et al, A Biomedical Program for Extended Space Missions, NASA-MSC (May 1969).

    c. The NASA Program for an Integrated Medical and Behavioral Laboratory Measurement System, by N. Belasco and S. L. Pool, M.D., NASA MSC, Houston, Texas.

    d. Candidate Experiment Program for Manned Space Stations, NASA Report NHB 7150.XX (15 September 1969).

14. Emergency Medical Treatment. The time required to bring an additional medical team onboard the OLS or the transit time required to return a patient to earth for further medical care is dependent on the following assumptions and/or conditions.

    a. A medical decision must be made that the patient either can or cannot be moved. The types and severity of a given injury that would preclude at least immediately of moving and subjecting the patient to the rigors of transit and earth reentry g forces are brain concussion, retinal concussion, spinal concussion, engorged appendix, broken ribs, and a crushed chest cavity.

b. Assume the injury or illness occurs between CIS flights, which would require emergency transfer of the patient by space tug, or for bringing the medical team to the OLS.

c. Assume that one OLS based tug is down on a 28-day lunar surface sortie.

d. Before the second lunar tug could leave the OLS for earth orbit, the lunar surface tug would have to abort their surface mission and return to the OLS.

e. Emergency transfer time from lunar orbit by space tug entails:

   24 hours of lunar orbit flight operations to TEI
   56 hours of TE coast time
   5 hours for earth shuttle rendezvous and docking or
   27 hours to rendezvous with the EOSS

(1) This adds up to a minimum time of 85 hours assuming a shuttle can be made ready and placed in an orbit coincident with that of the incoming space tug.

(2) If the space tug has to go to the EOSS to transfer the patient, a total of 107 hours will be required.

(3) The times given in items (1) and (2) will have to be extended by the time it takes to fuel and prepare the tug for an earth orbit mission. Present time estimates for tug refueling are between 8 and 12 hours. Perhaps the other tug checkout and preparation tasks can be accomplished during the 12-hour refueling so there would be no more than a 12-hour delay for space tug preparation.

(4) Additional time will be required for aborting the lunar surface tug sortie mission. The time here would be depending on the lunar surface flyer and rover missions. How far out are they and how long does it take to get them back to the space tug? And then, how long does it take to prepare the tug for launch to lunar orbit?

Also, it is necessary for the earthbound tug to await final OLS docking of the tug returning from the lunar surface, which assumes that the injured crewman being returned to earth was on the OLS and not from the lunar surface sortie crew? Before this emergency time to return to earth can be firmly fixed, the above questions concerning vehicle operations and lunar surface mission operations must be resolved.

f. For the case of taking a medical team out to the OLS from earth to provide care for injured crewmen that cannot be moved because of the nature of their injuries. The transit times out are approximately the same as those required for returning from lunar orbit. Also, the problems of shuttle and tug preparation times and availability must be resolved before minimum transit time can be determined.

g. See item 13 above for other medical requirements.

15. Crew Accommodations

a. See rationale number 4 for the overlap time.

b. Dual occupancy of staterooms (in either pressure volume) during emergencies has been tentatively set at 30 days for OLS operations with nominal 8-man crew based on the following assumptions and conditions:

(1) Emergencies can come into being from accidents of the following type or kind and the severity of each incident will generally dictate the length of time the emergency exists.

Fire
Mechanical damage
Explosion
Loss of pressurization
Fluid leakage
Collision
Food or water contamination
Meteoroid penetration
Loss of electrical power
Atmospheric contamination

(2) Assume mechanical damage on or within one pressure volume which renders it non-habitable until there is major replacement of hardware that must be procurred from earth.

(3) Assume the hardware is available but must be checked out and prepared for launch to EO, 3 days.

(4) Shuttle preparation can be accomplished during hardware procurement.

(5) CLS preparation can begin at the time of shuttle preparation.

(6) CLS windows for TLI occur approximately every 11 days. (Refer to Section 7.0 of Volume II)

(7) Assume that hardware procurement, shuttle preparation, and CLS preparation times for a special mission could cause slippage by at least one CLS window. Therefore, minimum time to CLS TLI including hardware procurement is 22 days.

(8) Assume the CLS time EO to LO is 128 hours plus 24 hours in lunar orbit or six days.

(9) The times for the above functions (items 7 and 8) add up to 28 days of transit time for special mission. This transit time plus 2 days for equipment installation and checkout sets the requirement for total crew occupancy within one pressure volume of the OLS at 30 days.

(10) This 30-day time span for a correctable OLS emergency sets the minimum time requirements for life support consumables and the capabilities of the supporting facilities in each pressure volume of the OLS for the case of OLS partial failures. (Reference Section 7.0 of Volume II)

16. EOSS developed requirement and rationale item 8 above.

17. EOSS developed requirements and rationale item 8.

18. EOSS developed requirements and Apollo crew equipment power requirements.

19. EOSS developed requirements and rationale items 8 and 9.

6.0 DOCKING PROVISIONS REQUIREMENTS

Docking provisions support and/or provide the capabilities for alignment and control of approaching tugs or other spacecraft from stationkeeping through docking. It also provides the capabilities for coupling and uncoupling crew and cargo modules. An area for a shirtsleeve environment to transfer crew, cargo, and equipment between the docked elements shall be provided. Docking provisions also contain the interfaces for supplying utilities to docked elements.

6.1 FUNCTIONAL REQUIREMENTS

6.1.1 Acquisition and Alignment

1. Provide means for visual, video, and radar contact.
2. Provide docking aids.
3. Provide mounting accommodations.

6.1.2 Controlled Mating

1. Provide precontact and contact alignment.
2. Provide capture.
3. Provide attenuation and stabilization
4. Provide pulldown.
5. Provide for hard dock latching.
6. Provide pressure seal.

6.1.3 Utilities Interface

1. Provide electrical power interface.
2. Provide information (data) interface.
3. Provide fluid transfer interface.
4. Provide pressurization interface.
5. Provide air circulation ducting.
6. Provide liquid cooling couplings.

7. Provide water supply and return.

8. Provide pumpdown capability.

6.1.4 Crew and Cargo Transfer

1. Provide transfer means.

2. Provide shirtsleeve transfer environment.

6.1.5 Thrust Loads and Docking Forces

Provide structural capability to withstand thrust loads and docking forces.

6.1.6 Structural Integrity

Provide structural integrity between the OLS and docked elements.

6.2 PERFORMANCE REQUIREMENTS

The docking function permits the OLS to meet a variety of operational, logistic, and safety requirements. It is a mechanical, fluid, electrical system that must operate effectively throughout the life of the OLS. Docking provisions shall be common to the cislunar shuttle and lunar landing tugs and other program elements that will be mated to the OLS.

6.2.1 Acquisition and Alignment of Docking Elements*(2)

1. Each docking port shall have at least one window. The window shall provide a minimum of ± 15 degree square field of view.*(2,6)

2. The interior of each docking interface shall be illuminated by low-level flush mounted lights.*(6)

3. At each docking port window, there shall be mounting provisions to physically attach the CCTV camera and the approach radar equipment.*(5,7)

4. Corner cube reflectors shall be provided at each docking port.

6.2.2 Controlled Mating *(3)

1. The docking function shall be capable of precontact and contact alignment for docking elements with the following velocity and alignment:

*For rationale, refer to specified numbered item in Section 6.5

a. Axial velocity (closing velocity) up to 0.5 feet per second

b. Radial velocity (cross-axis translation rate) up to 0.3 feet per second

c. Angular velocity (change of rate in attitude) up to 0.5 degrees per second

d. Radial alignment (centerline miss distance) up to 5 inches

e. Angular alignment (pitch and yaw misalignment) up to $\pm$ 4 degrees

f. Rotational alignment (roll misalignment) shall be limited to $\pm$ 4 degrees*(5)

2. The docking function shall provide capture of docking elements with a mass up to that of a cislunar shuttle at the -X axis port and the mass of a fully loaded tug plus propellant module at all other ports (5360 slugs).*(5,10)

3. The docking function shall be capable of attenuation of a force of 3750 pounds and stabilization within 90 seconds.*(4,5)

4. The docking function shall provide pull down of a 10-inch attenuation stroke.*(4)

5. The docking function shall provide hard dock accepting a force of 4000 pounds.*(4,5)

6. Pressure seal - provide a pressure-tight seal against the maximum atmosphere design pressure in either direction.

6.2.3 Utilities Interface*(5,6 - all utilities interfaces except where added rationale noted)

The docking function shall provide a standard utilities interface across all docking ports. The characteristics of the utilities interface are included below.

1. Electrical power capability provisions shall include two power connectors, 180 degrees apart. The characteristics of the electrical power available at each port shall be as follows:

*For rationale, refer to specified numbered item in Section 6.5

Average power demand of 4 kw at any docking port. Maximum sustained power demand shall be 6 kw for a duration of less than one hour; frequency of occurrence will not be more than twice in 24 hours.

Provisions shall be made to allow a docked element ground to be transferred to the OLS VGP and not use the docked element structure.

2. Information capability is included for the following:

   Provide mounting provisions for the connection to the internal communication busses.

   Provisions shall be made for the connection of a CCTV camera and receiver.

   Provisions shall be made for connection of two-way hardline voice communications between the docked elements.

3. Fluid Transfer. All of the docking ports shall provide for the following transfer of cryogenics:

Fluid	Transfer Restrictions
LO_2	Can be transferred same time as anything except LH_2
LN_2	Can be transferred same time
LH_2	Should be restricted transfer w/He purge before and after

4. Pressurization. Provisions shall be made for atmospheric pressurization at each docking port.

5. Air Circulation. Provisions shall be made for air circulation ducting at each docking port.

6. Liquid Cooling. Provisions shall be made for liquid cooling connections at each docking port.

7. Water. Provisions shall be made for water transfer connections at each docking port.

8. Pumpdown. Provisions shall be made for pumpdown ducting at each docking port.

6.2.4 Crew and Cargo Transfer

1. Provide means for crew and cargo transfer. Each docking port shall have a minimum clear 5-foot diameter opening.*(4,5,6,8)

2. Each docking port shall be maintained so that the latching and sealing of the docking port after hard dock will allow crew and cargo transfer between docked elements in a shirtsleeve environment.*(4,5,6,8)

6.2.5 Structural Capability to Withstand Thrust Loads and Docking Forces *(2,3,4,5,7)

The -X axis docking port shall have sufficient structural integrity to accept axial thrust loads of 38K pounds for orbital maneuvers and attitude control. All docking ports shall have sufficient strength to withstand docking and undocking induced forces.

6.2.6 Structural Integrity Between OLS and Docked Element*(5,7,10)

1. Each docking port shall be capable of maintaining for extended periods of time hard dock of a space tug of 15 feet diameter and 55 feet length (approximate weight of 85K pounds).

2. At least one docking port shall be capable of docking an electrical power module of 14 feet diameter, 38 feet length, and approximate weight of 11K pounds on the representative OLS; and 14 feet diameter, 42 feet length, and 24K pounds on the derivative OLS.

   Note: The on-orbit weight of the OLS for these calculations has been estimated at 157K pounds for the representative OLS and 222K pounds for the derivative OLS.

6.3 OPERABILITY

6.3.1 Reliability

Redundancy shall be provided as a minimum for each attenuator, latch mechanism, and seals (See Section 2.2).

6.3.2 Maintainability

See Section 2.2.

6.3.3 Useful Life

See Section 2.2.

*For rationale, refer to specified numbered item in Section 6.5

6.3.4 Environment

See Section 2.2.

6.3.5 Human Performance

See Section 2.2.

6.3.6 Safety*(8)

1. The capability shall be provided for the separation of unmanned docked vehicles from the OLS in the event of an uncontrollable emergency on the vehicle.

2. Provisions shall be made for the emergency sealing of docking ports in the event of unplanned leakage.*(5,7)

3. Two independent means shall be provided at each docking port for permitting personnel transfer.*(5,7)

6.4 MAJOR INTERFACES

6.4.1 Experiment Support

The docking function shall provide for logistic support of experiment resupply during normal operations by providing access to the logistics spacecraft.

6.4.2 Structures

1. The representative OLS core module structure shall provide for the attachment of six docking ports.*(1)

2. The structure shall provide additional support as required to strengthen the hard docked position.

3. The end docking port on the -X axis shall be sufficiently strong to withstand the axial thrust load of 38K pounds for use in earth and lunar orbital maneuvers and TLI attitude control.*(9)

4. The attachment of the docking port to the structure shall withstand the docking forces and internal pressure.

5. The docking port/structure interface shall be designed to fit the common NASA Space Program docking assembly.

6. Docking port requirements are given in Table 6-1.*(1)

*For rationale, refer to specified numbered item in Section 6.5

Table 6-1. Docking Provisions

OLS Representative Configuration, Docking Port Requirements	OLS
Power boom (for assembly)	1 (A)
Dual-support cargo module	1 (S)
Tug	*2 (B/T)
Experiment module (for assembly)	1 (B)
Spare	1 (B/T / A)
Subtotal	6
Additional OLS Derivative Configuration, Docking Port Requirements (for assembly)	
Crew quarters module	*2 (S)
Control center	*2 (S)
Galley and recreation	1 (S)
Cryogenic storage module	2 (S)
Subtotal	7
TOTAL	13
*One each in separate pressure volumes S - Side; A - Axial; B/T - Bottom and/or Top	

7. Four active/active docking adapters shall be provided for both the representative and derivative OLS configurations. These adapters will permit the mating of two elements in the OLS program which both have passive docking mechanisms.

6.4.3 Reaction Control Subsystem

1. The capability to refuel cryogenic tanks via any docking port shall be provided without EVA operations, regardless of whether or not the OLS is pressurized. The following capabilities shall be provided across the docking interface:

Transfer of liquid oxygen

Transfer of liquid hydrogen

Transfer of liquid nitrogen

A minimum of one fill and one vent connection for each fluid shall be provided.

6.4.4 Environmental Protection Subsystem

At each docking port, the docking function shall provide the attachment points so that the environmental protection subsystem can provide a docking port cover. This cover is required to protect the docking port against aerodynamic and boost loads during launch and to provide on-orbit protection from micrometeoroids when the docking port is not in use. Provisions shall be made for OLS remote opening of the protective cover at two docking ports for the initial docking operation.

6.4.5 Electrical Power Subsystem

The docking function shall provide at each common docking port accommodations for the following EPS utilities through the docking interface:

1. Two connections each with a five-wire ac 400 Hz circuit capable of 4.0 kw at 120 to 208 volts. The fifth wire being for structure ground.

2. Two connections for controls including redundant information subsystem.

3. When a vehicle or experiment is docked to the OLS, its ground system shall be transferred to the OLS vehicle ground point and shall not use the docked vehicle structure.

4. When a detached experiment or docked vehicle is on internal power with the OLS connected, the module power distribution shall prevent power flow from the docked vehicle to the OLS or vice versa.

5. Caution and warning functions for monitoring the docked vehicle will be provided by the OLS prior to energization of the power connection. Under no condition shall power be permitted on any wire of the docking function connections during connection/disconnection operations.

6.4.6 Environmental Control/Life Support Subsystem

1. The docking provisions will require that the docking port wall temperature is above the dew point prior to pressurization.

2. The ECLSS shall be supplied with the following interfaces:

   a. Attach points and clear area for personnel access with blower and ducting to supply the crew life support environment.

   b. Provisions for those docking ports which support the experiment module are as follows:

      (1) Fluid couplings for water delivery and return

      (2) Coolant loop couplings and heat exchanger

      (3) Provisions for gaseous O_2 supply

      (4) Provisions for O_2, N_2 pressurization supply

      (5) Provisions for air circulation

      (6) Provisions for pumpdown capability

6.4.7 Information Subsystem

1. Provide the capability to connect the internal communication busses and TV channels to docked elements.

2. Provide for two-way voice communication between the docked elements. Provide for up to three TV channels between docked elements.

3. Data channels shall be provided to perform a checkout of docked elements. The OLS internal computations and processing capability will be used to monitor the element subsystems and perform routine diagnostic exercises to verify module readiness for release from the OLS.

6.5 RATIONALE

The docking provisions are required to permit safe, routine operations and intervehicular transfer without extravehicular activities. During the OLS mission operations timeframe, a number of manned and unmanned spacecraft will require common docking provisions. The OLS's docking provisions will interface with tugs and while in earth orbit with the EOS as does the EOSS, and EOSS design data has been used as a basic rationale for the elements defined herein.

1. Docking Port Requirements. The six docking ports required for the representative OLS configuration are based on the mission model of two tugs, one power module, one dual-support cargo module, one experiment module, and one spare. The spare is required to permit servicing or repair of other docking locations, flexibility of tug operations

during lunar orbit logistics, and the docking of the LSB tug in the event of an LSB emergency should a full complement of docked vehicles be present. With the possible exception of the power module dock, the docking provisions would be the same at each location. In the event of emergencies requiring docking of a tug when the spare is in use, one of the docked elements can be transferred to a docking port not in use on another docked element.

The additional derivative OLS docking port requirements are based on the mission model of one power module, two core modules, two crew quarters modules, one galley module, two control center modules, two cryogenic storage modules, two tugs, one experiment module, and one dual-support cargo module.

2. Acquisition and Alignment. The docking port and provisions, as the final goal of the approaching vehicle, must provide target information to the controlling system. During the docking phase, docking provisions must support or provide verification that the OLS has acquired the approaching vehicle. The final approach and docking maneuver requires provisions to safely control the rates and orientation of the approaching vehicle. Considerations of safety and docking element momentum transfer indicates that the radar tracking and telemetry must be an active element in the acquisition and alignment phases of the docking maneuver.

3. Controlled Mating. Controlled mating is required for safety and design efficiency.

4. Commonality of Elements. The use of the docking provisions as an active, mechanical system over the OLS life indicates a stringent requirement for design adequacy and durability. The use of special purpose, dedicated docks could conceivably reduce the weight of individual ports, but safety and redundancy considerations makes the special purpose concept untenable. Many previous programs and studies have shown that commonality is preferred on those systems requiring multiple docking ports.

5. Operational Criteria. Requirements indicating operational loads and conditions are principally derived from prior EOSS efforts. Factors of safety are derived from Section 2.3, 4.1, and the mission operations described in Section 7.0 of Volume II.

6. Interface Requirements. The role of the docking provisions as the means used to satisfy intervehicle interface requirements results in a number of elements identified by reference to other subsystem sections. In those cases where the affected subsystem does not specify interfaces with an active docked

vehicle, data from the EOSS study have been used. In all cases it has been assumed that the docking provisions would support open-hatch operations with docked tugs. In the open-hatch situation, it is assumed that the OLS and the tug operate as an integral unit and can share utilities, crew, and information through the docking provisions.

7. Safety. See Section 2.3.

8. General. See Section 2.2.

9. Load Transmission. The -X axis docking port must be capable of transmitting the 38K-pound thrust loads imposed by a space tug during orbital maneuvers in earth or lunar orbit. The 250K-pound thrust loads imposed during cislunar flight will be transmitted from the cislunar shuttle through a larger thrust ring to the outer frame of the OLS.

10. Mass of Docked Elements. The OLS mission concept calls for the docking of the OLS to a cislunar shuttle prior to TLI at the -X axis port. There are two principal candidates for a CLS: the reusable nuclear stage (RNS) with a fully loaded mass of approximately 400K pounds (12.4K slugs) and the chemical propulsion stage (CPS-1) with a fully loaded mass of approximately 610K pounds (18.9K slugs). The other OLS docking ports must have the capability to accept a fully loaded tug plus propellant module of approximately 173K pounds (5.36K slugs). The mission concept does not call for the docking of the EOS to the OLS in earth orbit (approximately 290K pounds or 9K slugs).

7.0 SUBSYSTEM REQUIREMENTS

Functional and performance requirements defined for the Orbiting Lunar Station (OLS) subsystems are presented in this section. Rationales for requirements are included where the reasons for these requirements are not immediately obvious. OLS subsystem requirements were derived from EOSS subsystem requirements with an allowance made for the greater safety requirements of lunar orbit operations, increased logistics costs, the effect of lunar orbit environment, differences in the planned science program, and the different external system interfaces required during OLS operations.

A summary of the functional requirements for each subsystem with significant performance requirements is given below.

Structures Subsystem

The structure shall provide the following:

Habitable pressurized volumes for crew habitation and work

Shelter, support, and protection for other onboard subsystems

Internal storage capability for expendables and experiments

Shelter and mounting provisions for other functional program elements

Necessary safety provisions and aids for crew operations

Storage and protection of internal equipment during launch and ascent

Airlocks

1. The -X axis docking port shall have sufficient strength to withstand the 38K-pound thrust loads for orbital maneuvers and attitude control applied by a tug.

2. The structure shall provide for 240 square feet of internal laboratory floor space and 45 square feet for an experiment control center, which also serves as a backup OLS control center.

3. The structure shall provide for an experiment module which will accommodate those experiments that cannot be incorporated into the basic OLS configuration. These experiments shall have 110 square feet of mounting area normal to local vertical. The experiment module will also include an airlock with EVA capability for subsatellite service and repair.

4. The structure must accommodate a solar storm shelter which will protect the crew from major solar flare event radiation.

5. The representative OLS configuration requires six docking ports. The derivative OLS configuration requires 13 docking ports. Due to the particular characteristics of the modular concept, the derivative OLS configuration exceeds the minimum required docking ports.

Environmental Control/Life Support Subsystem

The ECLSS shall satisfy the following functional requirements:

Atmospheric storage and supply
CO_2 management
Atmospheric control
Active thermal control
Water management
Waste management
Hygiene
Food management
Special life support

1. The cabin atmosphere O_2 shall be maintained at a partial pressure of 3.1 psia minimum to 3.5 psia maximum. Nitrogen is the atmospheric diluent. The total atmospheric pressure shall be 14.7 psia with deviations to 10.0 psia minimum.

2. Provisions for eight men for 30 days shall be available in either pressure volume with one docked tug for additional crew support in the event of OLS emergencies.

3. Provisions for 20 men for 55 days shall be provided with two docked tugs for additional crew support in the event of LSB or CLS emergencies.

4. Capabilities shall be provided for an emergency repressurization of the OLS pressure volumes (20K cubic feet).

5. Storage capacity will be sized for 180 days without resupply.

6. A laundry will be provided.

7. No IVA/EVA activity is scheduled but a capability shall be provided for a 2-man IVA for four hours in the event of cabin depressurization due to meteoroid punctures.

8. The ECLSS will process a maximum of 29.5 lb/day of waste in addition to 30 lb/month of waste and trash from experiments.

Electrical Power Subsystem

Major EPS functions are:

Primary power generation
Secondary power generation
Energy storage
Power conditioning
Distribution control and wiring
Lighting

1. The average power requirement of the OLS for routine lunar orbit operations is 20 kw.

2. The EPS shall be capable of supplying 1.9 kw for one year of lunar orbit quiescent storage.

3. The EPS shall supply the OLS with 15 kw during an earth eclipse.

4. The EPS shall supply the OLS with 10 kw during solar flare events.

5. Primary power shall be regulated 400 Hz, 120/208 vac with a limited amount of 56 vdc available.

6. Power quality shall be per MIL-STD-704.

7. An average of 4 kw shall be supplied for experiment support. A peak power demand of 7 kw for one minute shall be available with a maximum sustained load of 6 kw for less than one hour.

Information Subsystem

ISS functional requirements include:

External communications
Internal communications
Tracking
Display and control
Data processing
Software

1. Five coherent duplex channels shall be provided for communications and tracking.

2. Beam pointing within 3 db beamwidths.

3. The ISS shall be responsible for medium-range tracking (1000 feet to 450 n mi from the OLS).

4. Data processing acquisition rate is 1×10^7 bps.

5. Data processing rate is 1×10^7 bps.

6. Data processing distribution rate is 1×10^7 bps.

7. Total operating memory for the data processing assembly shall be 256K words (8 memory modules, 32K words/module).

8. Baseline ISS storage capability (excluding archival storage) is 2.5×10^6 words minimum.

9. Experiment imposed ISS requirements:

   Digital - 6×10^6 bps peak
   3.5×10^{11} bpd maximum
   1×10^5 bps average

   Storage - 18K words operating memory
   1×10^6 words mass storage

10. The solar storm shelter shall include the backup command and control consoles.

Guidance and Control Subsystem

Guidance and control functions include:

OLS state vector update
Logistics vehicle state vector update
Reaction control subsystem command and control
Attitude stabilization and orbit maintenance
Free-flying experiment navigation and guidance
Subsystems checkout
Logistics support

1. Ephemeris accuracy -

altitude	$\pm$ 330 ft, 1 sigma
in-track	$\pm$ 880 ft, 1 sigma
cross-track	$\pm$ 490 ft, 1 sigma
orbit velocity	$\pm$ 25 fps, rms

2. OLS state vector within 1 spherical nautical mile of desired location (3 sigmas).

3. Experiment operations OLS stability:

3-axis attitude hold (continuous)	± 0.25 degree
3-axis attitude hold (30 minutes)	± 0.10 degree
3-axis attitude rate (continuous)	± 0.05 degree/second
3-axis attitude rate (30 minutes)	± 0.01 degree/second
Maximum acceleration transient	0.001 g
Maximum acceleration	0.01 g

4. Docking range uncertainty:

1000 feet to 100 feet	± 1 foot, 1 sigma
100 feet to contact	± 0.5 foot, 1 sigma

5. Docking contact conditions:

Lateral position deviation	± 0.5 foot
Lateral velocity deviation	± 0.3 fps
Axial velocity deviation	± 0.5 fps

Reaction Control Subsystem

The RCS performs the following functions:

Provides forces and moments for attitude control and stabilization
Provides forces for orbit maintenance
Cryogenic storage
Subsatellite propellant storage

1. Total impulse requirements based on zero-g operation for 180 days:

Representative OLS - 2.214×10^6 lb-sec plus 82,000 lb-sec for emergency

Derivative OLS - 2.663×10^6 lb-sec plus 81,000 lb-sec for emergency

2. The nominal OLS lunar orbit is 60 n mi polar in an X-POP Y flight mode.

3. The operating altitude limit in lunar orbit is 45 to 80 n mi.

4. Cryogenic storage requirements are (lbm):

	O_2	H_2	N_2	
Representative OLS	6823	1645	3551	(180 days
Derivative OLS	8042	1913	7349	storage)

5. Subsatellite N_2H_4 storage 180 days is 7811 lbm.

Environmental Protection Subsystem

The ENPS provides the OLS with:

Aerothermodynamic protection
Thermal protection
Micrometeoroid protection
Radiation protection

1. Heat rejection requirements on the representative OLS are 26.6 kw for the core and 5.8 kw for the power boom during light side operations and 23.4 kw for the core and 21.5 kw for the power boom during dark side operations.

2. Derivative OLS module heat loads vary from 0.4 kw on the cargo module to 8.0 kw in the galley module.

3. The micrometeoroid protection must assure a probability of no failure of crew or systems compartments of 0.9 for 10 years.

4. The ENPS must provide a solar storm shelter with the required shielding to limit the crew radition dose to the allowable limit during solar flare events.

7.1 STRUCTURES SUBSYSTEM

The structures subsystem provides the living and working quarters for the crew in orbit and contains their atmosphere. It contains mounting provisions and serves as a shelter for other OLS subsystems, functional program elements (FPE's), and personnel rescued from other spacecraft. It also provides a shelter for the storage of consumables and support for the docking ports and mechanisms for crew and equipment transfer.

7.1.1 Functional Requirements

The structure shall provide the following:

Habitable pressurized volumes for crew habitation and work*(1)

Shelter, support, and protection for other onboard subsystems*(2)

Internal storage capability for expendables and experiments*(2)

Shelter and mounting provisions for other functional program elements*(2)

*For rationale, refer to specified item number in Section 7.1.5

Necessary safety provisions and aids for crew operations*(1)

Storage and protection of internal equipment during launch and ascent*(2)

Airlocks*(9, 10)

7.1.2 Performance Requirements

Any differences between representative and derivative OLS structures performance requirements will be noted.

Launch and Ascent

The structure shall withstand without excess deflection or failure the loads imposed by the natural and induced environment during unmanned launch and ascent.

1. Natural environment (See Section 2.2 winds)

2. Induced environment (See Section 2.2)

   Internal pressure
   Temperature
   Acoustics
   Vibration
   Acceleration
   Max q alpha loads
   Aerodynamic pressure distribution
   Cutoff loads

3. The primary structure shall be designed to the following factors of safety for unmanned launch and ascent operations: *(4)

   Ultimate = 1.50
   Yield = 1.20

Earth Orbital

1. The structure shall withstand without excessive deflection or failure the following conditions: *(5)

   a. Natural environment (See Section 2.2)

      Atmosphere
      Thermal
      Radiation
      Meteoroid

*For rationale, refer to specified item number in Section 7.1.5

b. Induced environment (See Section 2.2)

Internal atmosphere
External atmosphere
Acceleration
Docking impact

2. The primary structure shall be designed to the following factors of safety for manned operations in earth orbit: *(6)

Ultimate = 2.00
Yield = 1.50

Short duration or transient loadings:

Ultimate = 1.75
Yield = 1.30

Translunar Injection and Lunar Orbit Insertion

1. The structure shall be designed to the following factors of safety for unmanned TLI and LOI: *(4)

Ultimate = 1.50
Yield = 1.20

2. The structure shall withstand without excessive deflection or failure the following conditions: *(3)

a. Natural environment

Thermal
Radiation
Meteoroid

b. Induced environment

Internal atmosphere
External atmosphere
Boost thrust and control forces

Lunar Orbit

1. The structure shall withstand without excessive deflection or failure the following conditions: *(5)

a. Natural environment (See Section 2.2)

b. Induced environment (See Section 2.2)

*For rationale, refer to specified item number in Section 7.1.5

2. The primary structure shall be designed to the following factors of safety for manned operations in lunar orbit: *(6)

   Ultimate = 2.00
   Yield = 1.50

   Short duration or transient loadings:

   Ultimate = 1.75
   Yield = 1.30

Structural - General

1. The -X axis docking port shall have sufficient strength to withstand the 38K-pound thrust loads for orbital maneuvers and attitude control applied by a tug.*(7)

2. The structure and docking ports shall have sufficient strength to withstand the forces induced during docking and undocking operations.*(5)

7.1.3 Operability

Structural mechanisms shall have the capability of fulfilling all required functions with no restrictions on station orientation.*(8)

Reliability

See Section 2.2.

Maintainability

Equipment and equipment support shall be so arranged that the entire inside of the pressure shell may be readily exposed for leak detection and repair. (See Section 2.2.)*(9)

Useful Life

See Section 2.2.

Environment

See Section 2.2.

Human Performance

See Section 2.2.

*For rationale, refer to specified item number in Section 7.1.5

Safety

1. The OLS shall be divided into two (or more) separately pressurizable volumes. Each volume will be capable of being sealed off from the other volume(s) and of holding the maximum atmospheric design pressure without structural failure while the other volume is evacuated, partially pressurized, or pressurized at the maximum design pressure.*(10)

2. An opening shall be provided that allows for crew transfer between two adjacent volumes in a shirtsleeve environment. This opening shall also be capable of allowing the transfer between volumes of cargo 5 feet in diameter. The opening shall be capable of providing a pressure-tight seal against the maximum atmospheric design pressure in either direction.*(11)

3. An internal airlock will be provided that allows for the transfer of IVA personnel between adjacent separately pressurizable volumes when a pressure differential exists or one volume is contaminated. The airlock shall have the capability of accommodating two pressure-suited men with backpacks or with umbilicals. One man may be incapacitated. Transfer of the two men shall be possible unaided by other personnel. The airlock shall have the capability of pressurized or depressurized operation with either of the two connecting volumes depressurized.*(10)

   Use of the airlock shall not cause a rate of pressure drop of more than 0.5 psi/second in the connecting volumes for normal operations. Higher rates are acceptable for emergencies. Three cycles of airlock operations shall not cause the atmospheric pressure in the pressurized volume to drop below 62 percent of the normal operating pressure. *(12)

4. The capability shall be provided that allows the transfer of EVA personnel from one of the pressurizable volumes to and from space. This airlock shall be capable of accommodating two pressure-suited men with backpacks or with umbilicals. One EVA man may be incapacitated. Transfer of the two men shall be possible unaided by the other personnel. The airlock shall be capable of pressurized or depressurized operation with the connecting volume(s) either pressurized or depressurized. Use of the airlock shall not cause a rate of pressure drop of more than 0.5 psi/second in the connecting volumes for normal operations. Higher rates are acceptable for emergencies. Three cycles of airlock operations shall not cause the atmospheric pressure in any pressurized volume to drop below 62 percent of the normal operating pressure.*(12)

*For rationale, refer to specified item number in Section 7.1.5

5. Two openings shall be provided between adjacent decks of the OLS. One opening shall be capable of accommodating personnel and cargo of 5 feet in diameter (not simultaneously). The other opening will be used as an auxiliary (shirtsleeve) exit for personnel. Each of the two openings shall be provided with an air-tight cover to prevent the transfer of contaminants and smoke in an emergency. The internal airlock may be used as an auxiliary exit on the appropriate decks.*(13)

6. Staterooms, laboratories, toilets, and other areas with restricted access shall provided two separate entry-egress paths for personnel. The two separate paths shall, where possible, lead to different areas on the deck. Where it is not practical to provide doors or normal access routes, the second entry-egress paths may be provided by knockout panels for emergency use. These panels should have the capability of being opened from either side.*(11)

7. At least two egress paths shall be available from each pressurizable volume for emergency egress of personnel during manned ground operations. One external emergency exit shall be available on each pressure volume. The external emergency exits will open outwards and will be compatible with the escape provisions in ground operations.*(13)

8. Dual access routes shall be provided so that no single failure can deny crew access to docking port(s).*(13)

7.1.4 Major Interfaces

Structure Experiment Support

1. Internal floor area:

Experiment control center	45 square feet
Photo laboratory	70 square feet
Data analysis laboratory	70 square feet
Geochemistry laboratory	100 square feet

2. The structure shall make provisions for an airlock laboratory located in an experiment module for integral experiment use as follows:

   a. The airlock shall be sized to accommodate all remote sensors (11,000 through 15,000 series equipment items) and subsatellite servicing (60,000 series equipment items) in accordance with the Experiments Operating Plan. Airlock minimum dimensions shall be 5-foot diameter and 10 feet long. (Rationale (7, 12) in Section 4.0)

*For rationale, refer to specified item number in Section 7.1.5

b. The airlock shall be capable of being pressurized and depressurized three times per year.

c. The experiment module shall provide 110 square feet mounting area normal to local vertical.

d. The airlock shall permit shirtsleeve crew access to film and tape cassettes of experimental equipment mounted within the airlock while all sensors are in a deployed mode.

e. The airlock shall contain the following utilities:

Electrical power
Thermal control (of instruments via ECLSS)
ISS data and communication hardlines
O_2 and N_2 (instruments)
Cryogenics
Storable propellant
Subsatellite docking provisions (as required to satisfy Experiments Operating Plan)

Docking provisions shall include a docking port with a minimum clear 5-foot diameter opening that will permit crew egress/ingress for EVA activities. (Refer to Rationale (5) in Section 4.0)

g. The following utility hookups shall be provided at the subsatellite docking interface:

Electrical power
Thermal control
ISS data hardlines
O_2 and N_2 (for instruments)
Propellant transfer

3. The structure shall withstand the docking forces of the free-flying subsatellites.

4. Provisions shall be made for deployed experiment sensors to have an unobstructed view from nadir to 5 degrees above the lunar horizon.

5. The structure shall provide a location close to OLS reference for onboard experiments that require base-motion isolation for greater accuracy or tracking capability. Where possible, experiments with similar pointing, tracking, and view angle requirements will be mounted on the same gimbal structure.

6. The structure shall provide suitable mounting accommodations for experiments so that installation, maintenance and replacement may be accomplished without EVA.

Crew Habitability

1. General.

The OLS interior shall be designed in accordance with good architectural and decorator practices in order to provide comfortable, efficient and attractive living and working spaces. The interior arrangement shall insure crew comfort, efficiency, and physiological and psychological well-being. The arrangement of all equipment within a given area shall be in an upright (earth-like) orientation.

The space station interior shall be partitioned into basic functional areas including the following:

Individual crew staterooms
Food preparation, preservation and serving areas
Wardroom and recreation areas
Personal hygiene and laundry facilities
Solar storm shelter
Medical treatment area
Control stations
Laboratories, experiments areas
Storage areas
Subsystems areas
Aisles, passageways, tunnels
Docking ports and airlocks

Mounting provisions shall be provided throughout the station for mobility aids and restraints, including handholds, guiderails, footholds, and/or tethers required for crew locomotion and/or bracing/stabilization. Design features which should be considered include:

Spacing of mobility aids shall be such that either these devices, vehicle structure, or equipment/ accommodations shall always be within reach of a crewman.

Mobility aids shall be mounted on equipment or accommodations where appropriate as well as on vehicle structure.

Design of vehicle structure equipment and accommodations shall consider features which inherently provide a mobility aid capability.

Handholds shall be either the rigid, flexible or recessed type, as appropriate to a specific location.

Guiderails shall be located between 36 inches and 40 inches above the floor and shall be provided on both sides of aisles and passageways.

Handholds shall be appropriately located with respect to crew mobility requirements.

A continuous guiderail shall be provided for crew interdeck transit. The cargo transport device may provide the capability for this purpose.

Where ladders are provided for interdeck transit, the clearance behind ladders to a surface or bulkhead shall be no less than 6 inches, and the climbing space in front of ladders shall be a minimum of 32 inches wide by 32 inches deep.

The wall-to-wall area requirements are included in Table 7-1.

All equipment installed within the OLS shall be such that access to the pressure hull can be readily achieved for inspection and/or repair. The access provisions shall be such that a suited/pressurized crewman can gain access to the pressure hull (equivalent of a minimum 32 inches by 78 inches accessway). The access requirements are listed in Table 7-2.

Provisions shall be made for illumination as shown in Table 7-3.

2. Crew Accommodations.

There shall be eight individual crew staterooms designed for single occupancy during routine operations and dual occupancy during periods of crew overlap or emergencies. Occupancy during routine operations shall be considered to be 180 days. Dual occupancy during overlap for periods up to 16 days, and occupancy during emergencies for periods up to 30 days.

The staterooms shall be divided equally between two separate pressure volumes with the commander's and tug commander's staterooms in different volumes.

Table 7-1. Wall-to-Wall Requirements

FUNCTIONAL AREA	8-MAN OLS (SQ. FT.)
CREW STATEROOMS ($50\ ft^2$/ man)	400
PRIMARY GALLEY	56
BACKUP GALLEY	40
DINING	44
RECREATION	80
EXERCISE	60
MEDICAL	144
PERSONAL HYGIENE AND STORAGE	192
LAUNDRY	35
PRIMARY CONTROL CENTER ***	100 **
BACKUP CONTROL CENTER	45 *
PHOTO LAB	70
DATA ANALYSIS LAB	70
GEOCHEMISTRY LAB	100
TOTAL	1436

* Including 1 console (48 x 31 x 50 in.)

** Including 2 consoles (48 x 31 x 50 in. each)

*** Additional OLS space required for accommodation of 7 experiment mass-memory modules (12 x 18 x 14 in. each)

Table 7-2. Access Requirements (Hatchways/Doors)

Functional Area	Height (Inches)		Width (Inches)	
	Minimum	Preferred	Minimum	Preferred
General crew staterooms	78	82	28	30 - 32
Commanders stateroom	78	82	28	30 - 32
Tug commanders stateroom	78	82	28	30 - 32
Primary galley	78	82	32	36 - 42
Backup galley	78	82	32	36 - 42
Dining area	78	82	32	-
Recreation area	78	82	32	-
Personal hygiene area	78	82	32	36
Crew exercise area	78	82	32	-
Medical treatment area	78	82	32	36 - 42
Crew work station	78	82	28	30 - 36

3. Galley Requirements.

a. Provisions shall be made for a galley which is capable of providing the nutritional needs of the 8-man crew.

b. The galley shall be capable of being occupied by up to two crewmen simultaneously during periods of food preparation. The galley shall be capable of serving a minimum of four crewmen simultaneously.

c. A backup galley shall be provided which is capable of satisfying the nutritional needs of the 8-man crew for a period of at least 30 days.

d. The backup galley shall be in the opposite pressure volume from the primary galley.

Table 7-3. OLS Lighting Requirements (Foot-Candles)

Area	Overhead (1)	Supplementary Local (2)	Emergency (1)	Low Level (1)
Crew staterooms (6)	30	Desk 50 Bunk 50	5	0.5
Primary galley	50	Work counter 50-70	5	0.5
Backup galley	10	Work counter 30	5	0.5
Primary dining	variable to 30 (3)	Eating surface 30-50	5	0.5
Recreation	variable to 30 (3)	30-50	5	0.5
Personal hygiene			5	0.5
Lavatories	30	50	5	0.5
Toilets	30		5	0.5
Showers	30		5	0.5
Exercise	30	-	5	0.5
Medical	Selectable 50 and 150	Work counter 50-70	100 diffused 500 (4)	0.5
Work stations				
Maintenance/repair	30-50	Work counters 50-70	10	0.5
Experiment	30-50	Work counters 50-70	10	0.5
Control centers	variable 5-50		10	0.5
Airlocks	30		5	0.5
Aisles, passageways Tunnels-direct diffused	30			0.5

(1) Foot-candles are measured 30 inches above deck.
(2) Unless specified, intensities are measured at the surface of use.
(3) Variable lighting to 30 foot-candles may be designed with 0.5 foot-candle low limit to provide night light.
(4) Auxiliary diffused illumination of 500 foot-candles will be provided, automatically actuated in event of power failure.
(5) Diffused 500- to 1000-foot-candle lamp shall be located above the examination chair and be directionally adjustable in medical and dental area.
(6) Low-level lighting shall always be on except when emergency lighting is in use.

e. The backup galley shall be capable of preparing and serving only dried (rehydratable), thermo-stabilized (canned), or other types of packaged food not requiring special preparation equipment or refrigeration or other preservation techniques.

4. Dining Area Requirements.

a. One dining area shall be provided which is capable of accommodating up to four crewmen simultaneously during periods of routine operations.

b. OLS crewmen shall utilize staterooms, aisles, or other available space as backup for the dining area.

5. Recreation Area Requirements.

a. A recreation area shall be provided which shall be utilized by the crew for relaxation and entertainment during off-duty hours.

b. The recreation area shall be located adjacent to the primary dining area.

c. The recreation area shall be capable of accommodating up to four crewmen simultaneously during periods of routine operations. The area shall be used in conjunction with the dining area to provide accommodations for up to 8 men for purposes other than recreation such as meetings.

6. Personal Hygiene Requirements.

a. The personal hygiene facilities shall be divided equally between the two pressure volumes and shall be located on the same decks as the individual crew staterooms.

b. Equipment shall be arranged to maximize personal privacy and to minimize interference between crewmen using adjacent equipment. Screens/doors shall be provided in front of the toilets and shower dressing areas for personal privacy.

7. Crew Exercise Area Requirement. A crew exercise area shall be provided for crew conditioning and physical fitness and be located adjacent to or as a part of the medical area.

8. Medical Treatment Area Requirements.

   a. One medical treatment area for routine crew monitoring shall be provided. The medical treatment area shall also be capable of supporting the diagnosis and treatment of crew injuries and illnesses.

   b. To provide the medical support required for the OLS, the medical area must have one each of the following facility capabilities:

      Examination table
      Sterilizer
      Refrigerator/freezer
      Field type x-ray
      Sink, lavatory
      Work surface
      Set of medical diagnostic equipment

9. Intervolume Airlock Requirements.

   a. An intervolume airlock capable of accommodating two crewmen simultaneously shall be provided between pressure volumes.

   b. The airlock shall have a minimum height of 84 inches and a minimum diameter of 60 inches for a cylindrical airlock, or equivalent.

   c. Outward opening hatches and associated actuating mechanisms for access to and egress from each pressure volume shall be provided.

10. Requirements for Aisles, Passageways, and Tunnels.

   a. Aisles, passageways, or tunnels shall be provided wherever crew, cargo, or equipment transfer is required.

   b. Aisles and passageways for crew transfer only shall have a minimum width of 32 inches with 36 inches to 42 inches preferred. The height shall be a minimum of 82 inches with 86 inches preferred. A height of 84 inches shall be considered as nominal.

   c. Tunnels for crew transfer only, which are less than seven feet in length, shall have a minimum diameter of 42 inches; tunnels which are greater than seven feet shall have a minimum diameter of 48 inches.

11. Acoustic Noise Limitations.

    a. Acoustic noise levels shall be maintained such that no adverse psychophysiological effects will be produced.

    b. Noise levels shall not cause discomfort to crewmen nor interfere with communication between crewmen at normal voice levels up to distances of 18 feet.

    c. Continuous noise levels shall not exceed 50 decibels in the speech interference level (SIL) range (600 to 4800 Hertz), 70 decibels at frequencies below SIL, nor 60 decibels at frequencies above SIL.

    d. The maximum acoustic noise levels during unmanned operations for various frequencies, in relation to OLS function areas, shall be in accordance with the values specified in Figure 5-4 of Section 5.0.

12. Vibration Limitations.

    a. Vibration emitting equipment shall not be located in crew living areas, and where required in crew work areas, shall be shock-mounted, insulated, or otherwise dampened so as not adversely affect crew performance.

    b. Where necessary, seating and restraint devices shall incorporate provisions to absorb perceptile vibrations.

Docking Provisions

1. The structure shall provide for the minimum number of docking ports at the locations specified in Table 6-1 of Section 6.0.

2. The structure shall provide additional supports as required to strengthen the hard-docked position.

3. The end docking port on the -X axis shall be sufficiently strong to withstand an axial thrust load of 38K pounds for use in orbital maneuvers and attitude control. (See Rationale #9 of Section 6.0.)

4. The attachement of the docking port to the structure shall withstand the docking forces and internal pressure.

5. The docking port/structure interface shall be designed to fit the common NASA Space Program docking assembly.

Reaction Control Subsystem

The liquid oxygen, hydrogen, nitrogen, and hydrazine tanks shall be located in unpressurized areas within the environmental shield of the OLS in redundant locations for reliability.

Electrical Power Subsystem

1. Lighting Protection. Structures shall provide electrical bonding between vehicles and appropriate ground connections to protect the OLS while mated to the launch vehicle on the pad at KSC against static electricity buildup and lighting surges. (See Rationale #4 of Section 7.3)

2. Harness Ducts. Redundant primary power and electrical harness ducts shall be provided for distribution of power throughout the OLS, including the pressure bulkhead feedthrough plates. (See Rationale #4, #20, and #21 of Section 7.3)

3. Heat Dissipation. Electrical cable runs shall take full advantage of the OLS structure for heat dissipation. Cable troughs should be designed to afford maximum heat transfer. (See Rationale #23 of Section 7.3)

7.1.5 Rationale

1. It is necessary for crew safety considerations.

2. It is required to maintain acceptable environment to ensure operability and reliability.

3. It is necessary to maintain complete structural integrity during launch and ascent and TLI, LOI mission phases to ensure crew safety and OLS operability during subsequent manned mission phases. The environmental parameters listed have been determined to have a potential significant influence on structural integrity.

4. Conservative design factors of safety have been selected for the launch-ascent phase to accomplish the following objectives:

    a. Provide high confidence in general structural integrity during this mission phase.

    b. Minimize the possibility of permanent structural deformations that could have adverse influence on the operation of mechanisms or alignment accuracy of experiments, antennas, guidance and control equipment, etc.

c. Provide the potential for reducing cost and complexity of environmental simulation during structural verification test programs.

d. Provide the potential to conduct adequate structural verification tests to a level below design ultimate loads. This would minimize the possibility of damage or destruction of the structural test article so that it could be programmed for additional ground test utilization.

5. It is necessary to maintain complete structural integrity to insure crew safety and OLS operability. The environments listed have been determined to have potential effect on structural integrity.

6. Conservative design factors of safety have been selected for manned mission phase to accomplish the following objectives:

   a. Provide high confidence in general structural integrity and resulting crew safety.

   b. Minimize the possibility of undesirable creep deformations under long-term sustained stress conditions.

   c. Additional considerations as described in items 4c and 4d.

7. An active docking system is employed to permit the attachment of passive elements, such as cargo modules, etc. Structural strength for indicated thrust load is required to permit orbital maneuvers by using a tug as a propulsive vehicle.

8. Complete freedom of station orientation is required to ensure adequate operational capability considering various scientific and experiment requirements.

9. Provision for inspection and repair of the pressure shell is necessary to ensure crew safety and to achieve 10-year operational life.

10. Necessary to insure crew safety and to permit structural repair if required to achieve 10-year operational life.

11. It is necessary to ensure crew safety and habitability and to facilitate cargo transfer from one pressure volume to another.

12. The maximum rate of pressure drop is based on crew comfort considerations. The requirement for minimum pressure of 62 percent normal operating pressure provides a partial pressure of oxygen of 1.9 psi, which is the minimum pressure adequate to support body physiological functions.

13. Dual openings between decks, exits from any compartment, and access routes to docking ports are provided to ensure crew safety during emergency conditions resulting from any credible accident. Sufficient separation between these provisions is required so that no single accident can incapacitate both routes.

7.2 ENVIRONMENTAL CONTROL AND LIFE SUPPORT SUBSYSTEM

The environmental control life support subsystem (ECLSS) provides essential atmospheric gases, temperature, pressure, humidity control, food storage and preparation provisions, water and waste management, and personal hygiene facilities and materials for OLS operation with an 8-man crew. In addition, special life support capabilities are provided for logistic operations overlap and emergency conditions.

7.2.1 Functional Requirements

The environmental control life support subsystem (ECLSS) shall provide the flight crew with a conditioned shirtsleeve environment. The subsystem shall provide necessary heating and cooling gas, fluid, and food supplies to support human life and equipment operation. Capabilities for storage and transfer of consumables and waste materials will be provided. The subsystem shall be capable of providing environments for onboard experiments.

The ECLSS shall satisfy the functional requirements described below.

Atmospheric Storage and Supply

Provide storage and supply of oxygen and nitrogen.

CO_2 Management

Provide carbon dioxide collection, control, and reduction.

Atmospheric Control

1. Provide atmospheric pressure, temperature, and humidity control.

2. Provide for the reclamation of waste waters excepting fecal water.

Waste Management

1. Provide for collection, transfer, processing, and storage or disposal of urine, fecal material, and waste materials.

2. Provide for disinfection of microbiologically and bacteriologically contaminated waste materials.

Hygiene

Provide facilities, equipment, and materials for housekeeping and personal hygiene.

Food Management

Provide for food storage, preparation, serving, and disposal.

Special Life Support

1. Supply and store emergency life support breathing oxygen and survival water.

2. Provide for IVA/EVA servicing.

3. Provide fire control and detection.

7.2.2 Performance Requirements

The ECLSS shall meet the performance requirements delineated in the following paragraphs. These requirements are arranged in the same order as the functional requirements contained in paragraph 7.2.1. Any differences between representative and derivative OLS ECLSS performance requirements will be indicated.

Atmospheric Storage and Supply

The OLS atmopshere storage and supply shall consist of a mixture of oxygen and nitrogen. The cabin atmosphere oxygen shall be maintained at a partial pressure of 3.1 psia minimum to 3.5 psia maximum. Nitrogen shall be used as the atmospheric diluent. The total atmospheric pressure shall be maintained at a nominal 14.7 psia with deviations to a minimum of 10.0 psia allowable.*(1)

1. Oxygen/Nitrogen Quantities

   The quantities of oxygen and nitrogen to be provided shall be based on the following consumption/use/loss requirements:

*For rationale, refer to specified numbered item in Section 7.2.5

a. Metabolic consumption (O_2) *(2)

Crew	1.84 lb/man-day nominal
Crew overlap	1.84 lb/extra crewman/day for 16 men for 16 days maximum
OLS crew emergencies	Provisions for 8 men total for up to 30 days in either pressure volume, with one docked tug for additional crew support.*(20)
LEP systems crew rescue (LSB or CLS)	Provisions for 20 men total for up to 71 days in the OLS with two docked tugs for additional crew support. (For rationale, refer to Section 7.0 of Volume II)

b. Leakage losses (O_2 and N_2)

OLS (design)*(3)	24 lb/day total for the representative OLS; 52 lb/day total for the derivative OLS

c. Pressurization uses (O_2 and N_2)

Exper. laboratory airlock	200 cubic feet volume, 3 times per year
Docking ports	116 cubic feet volume, 2 times per month
Intervolume/EVA airlock	175 cubic feet volume, zero times per month (no scheduled IVA/EVA activity)
Experiment module	1200 cubic feet, 3 times per month

2. Repressurization

Capabilities shall be provided for an emergency repressurization of the OLS pressure volumes (20,000 cubic feet) from gas stores.

*For rationale, refer to specified numbered item in Section 7.2.5

CO_2 Management

The CO_2 management assembly shall meet the following performance requirements:

1. The assembly shall be designed in accordance with carbon dioxide (CO_2) reduction to recover oxygen for reuse.

2. The assembly shall be capable of processing the following amounts of CO_2 generated by the crew: 2.25 lb/man-day nominal, 3.0 lb/man-day maximum.*(4)

Atmospheric Control

The OLS atmospheric control assembly shall meet the following performance requirements in controlling the OLS atmosphere:

1. Temperature. Atmosphere temperature shall be selectively maintainable on an area basis as follows: *(5)

   a. 60 F to 75 F in exercise areas

   b. 65 F to 80 F in personal hygiene areas

   c. 65 F to 75 F in all other areas

   All appropriate habitable compartments or enclosed areas shall have independent temperature control (crew compartments, galley, personnel hygiene areas, exercise areas, etc.)*(6)

2. Pressure. The station atmospheric total pressure shall be maintained at 14.7 psia nominal with deviations to a minimum of 10.0 psia allowable. Oxygen partial pressure shall be maintained between 3.1 psia minimum to 3.5 psia maximum.*(7)

3. Surface Temperature. The crew shall not be exposed by contact to any surface temperature which exceeds 105 F maximum and 57 F minimum.*(8)

4. Dew Point. The station atmosphere dew point temperature shall not exceed 57 F maximum.*(8)

5. Air Velocity. The station atmosphere air velocity shall be maintained between 15 fpm minimum and 100 fpm maximum with a nominal of 40 fpm.*(8)

6. H_2O Partial Pressure. The station atmosphere H_2O partial pressure shall be maintained within 8 mm Hg to 12 mm Hg.*(8)

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*For rationale, refer to specified numbered item in Section 7.2.5

7. Condensation. No condensation shall be allowed to form on internal surfaces.*(9)

8. Trace Contaminants. The station atmosphere trace contaminants shall be monitored and controlled to 0.1 of the threshold limit value per constituent.*(10)

9. The concentration of bacteria in the atmosphere within the pressurized compartments containing crew quarters, process laboratories, or experimental facilities shall be monitored and controlled.

Active Thermal Control

The active thermal control assembly shall have the following performance requirements:

1. Derivative OLS module heat loads are given in Table 7-4.

2. The radiator subassembly shall be capable of rejecting heat loads shown in Table 7-5 for the representative OLS configuration.

3. The thermal control assembly shall operate with no restrictions to module orientation relative to the moon and sun.

4. A temperature control loop shall provide 40 to 100 F heat sink capability for equipment temperature control.*(11)

5. Subsatellite thermal control provisions.

Water Management

The water management assembly shall have the following performance requirements:

1. Quantities of potable water for food and drinking shall be provided as follows: *(4,12)

   Food - 1.44 lb/man-day (freeze dry)
   Food - 0.96 lb/man-day (wet)
   Drink - 4.14 lb/man-day
   (Residual - 0.22 lb/man-day loss)

   Total 6.32 lb/man-day

   Latent loss - 3.09 lb/man-day

*For rationale, refer to specified numbered item in Section 7.2.5

Table 7-4. Derivative OLS Module Heat Loads

Module	Heat Load (kw)
Cargo module	0.4
Core 1A	4.8
Core 1B	4.3
Control center module 1	4.3
Control center module 2	4.3
Galley module	8.0
Crew quarters module 1	7.2
Crew quarters module 2	7.2
Power module	6.6

Table 7-5. Heat Rejection Requirements

	Light Side (Solar Cell)		Dark Side (Fuel Cell)	
	Core	Boom	Core	Boom
Subsystems	24.0 kw	0 kw	21.0 kw	0 kw
EPS Efficiency				
Distribution	1.5	4.5	1.3	4.0
Fuel cell	0	0	0	17.5
Electrolysis	0	1.3	0	0
Metabolic	1.1	0	1.1	0
Total	26.6 kw	5.8 kw	23.4 kw	21.5 kw
	(90,000 Btu/hr)	(19,800 Btu/hr)	(80,000 Btu/hr)	(73,500 Btu/hr)

2. Quantities of water for housekeeping and personal hygiene shall be provided as follows: *(12)

Washing - 4.0 lb/man-day
Shower - 17.2 lb/man-shower
Dishwashing and housekeeping - 3.0 lb/man-day
Laundry - 4.0 lb/man-day

*For rationale, refer to specified numbered item in Section 7.2.5

3. Cold water shall be supplied at a temperature of 50 ± 5 F and hot water at 155 ± 5 F for the purpose of food reconstitution.*(13)

4. Potable water shall be provided for hygienic flushing of urinals, 3.5 lb/man-day.*(12)

5. Quantities of water for experiment use shall be provided at a rate of 35 lb/day maximum.

6. The water system shall be designed for closed-loop operation for reclamation, storage, and reuse, excluding fecal water.*(14)

Waste Management

The waste management assembly shall meet the following performance requirements:

1. Urine waste shall be collected and processed and the water reclaimed for reuse. Solids shall be collected and processed. Quantities of urine wastes to be processed shall be as follows: *(4)

   Urine water - 3.45 lb/man-day nominal
   - 4.48 lb/man-day maximum

   Urine solids - 0.13 lb/man-day

2. Fecal wastes shall be collected and processed. Fecal water shall not be reclaimed. Quantities of fecal wastes to be processed shall be as follows: *(4)

   Fecal water - 0.25 lb/man-day nominal
   - 0.33 lb/man-day maximum

   Fecal solids - 0.13 lb/man-day

3. One toilet facility consisting of separate fecal and urine collection devices in each pressure volume. In addition, two wall-mounted urinals shall be provided for added crew convenience. One urinal shall be located in each pressurized volume.

4. Quantities of food wastes to be collected and processed shall be as follows: *(12)

   Food wet wastes - 0.40 lb/man-day
   Food packaging - 0.60 lb/man-day

*For rationale, refer to specified numbered item in Section 7.2.5

5. Miscellaneous wastes such as paper, clothing, film containers, etc., shall be collected, processed, and stored for logistics return. Provisions for processing 29.5 lb/day maximum with a compacted volume of 0.4 cubic feet and uncompacted volume of 2.0 cubic feet shall be provided.*(12)

6. Waste solids shall not be dumped to space.*(15)

7. Microbiologically and bacteriologically contaminated waste materials shall be disinfected as close as possible to their source prior to storage, processing, or disposal.*(16)

Hygiene

The hygiene assembly shall meet the following performance requirements:

1. Housekeeping provisions storage space of approximately 35 cubic feet shall be provided.

2. Each of two shower facilities, one within each pressurized volume, *(17), shall provide capability for sequential showering of two to three crewmen in any 12-hour period. However, the shower frequency will be two showers/man-week.*(12)

3. Six sinks for washing shall be provided.

Food Management

The food management assembly shall meet the following performance requirements:

1. A galley shall be provided with facilities for preparing and serving food for at least four men at a time, nominal.

2. A backup galley shall be provided with capabilities for storing at least 30 days supply of dried food. The facility shall provide hot and cold water for food reconstitution.

3. A freezer with 70 cubic feet internal capacity and a refrigerator with 10 cubic feet internal capacity shall be provided.*(12)

Special Life Support*(18)

The special life support assembly shall meet the following performance requirements:

*For rationale, refer to specified numbered item in Section 7.2.5

1. An O_2 high-pressure storage assembly shall be provided. This assembly shall have capability for supplying O_2 for intravehicular activities. In addition, the assembly shall provide O_2 for recharging portable life support equipment for extravehicular activities.

2. The ECLSS shall provide EVA/IVA support with the following capabilities:

   IVA Support

   O_2 nominal maximum flow - 8 lb/man-hour
   O_2 emergency flow - 22 lb/man-hour for 30 minutes
   O_2 inlet temperature - 40 to 64 F
   Heat load - 2000 Btu/man-hour for 3 hours
   Suit pressure - source regulate to 110 psig
   LCG water flow - 240 lb/hour at 43 F
   Design capacity - 4-hour operation

   PLSS Charging

   O_2 per recharge - 1.6 lb
   H_2O per recharge - 10.8 lb
   Recharge pressure - 1410 $\pm$ 30 psi
   Temperature - 70 to 90 F
   Design frequency - No use anticipated

3. An emergency reserve of high pressure oxygen for 8 men for 30 days plus leakage shall be maintained in each pressurized volume. The water reserve shall be maintained from the normal 180-day storage capacity.

4. Emergency fire control and detection provisions shall be provided. These provisions shall, as a minimum, contain an oxygen face mask and O_2 bottle and a CO_2 extinguisher for small fire control. Atmospheric dump provisions shall be provided for large fire control. A total of 16 O_2 masks and bottles, 8 in each pressure volume, will be provided.

7.2.3 Operability

Reliability

The environmental control life support subsystem reliability requirements are specified in the following paragraphs.

1. Atmospheric Storage and Supply

   The O_2 - N_2 storage and supply capability shall be provided for independent supply sources for each pressure volume.

2. CO_2 Management

   a. Redundant elements are required for CO_2 removal, one located in each pressure volume.

   b. A single element for CO_2 reduction is required, with a maximum downtime for maintenance of 24 hours.

3. Active Thermal Control

   a. Provisions are required for accomplishing the temperature and humidity control independently in each pressure volume.

   b. Two coldplate cooling loops for experiments and equipment shall be provided, one for each pressure volume.

   c. A minimum of two coolant loops shall be provided for heat rejection.

4. Water Management

   Provisions shall be made in each pressure volume for independent, redundant water reclamation, storage, and supply.

Safety

The environmental control life support subsystem shall meet the following safety requirements.

1. A 30-day margin of consumables, as a minimum, shall be maintained onboard within each pressure volume.*(4)

2. The capability shall be provided to verify the safe environment and the safe operational status of activated subsystems within the orbiting vehicle prior to personnel entry, initially, and prior to reentry following temporary evacuation of the whole vehicle.

3. The capability shall be provided for providing a habitable shirtsleeve atmosphere, humidity control, temperature control, fluid and food supplies, hygiene, and waste management requirements for the whole crew for a minimum period of 30 days (1) with any one pressurizable volume deactivated, isolated, and vacated due to an accident or (2) with any credible combination of a subsystem deactivated, as a result of an accident, and a portion of redundant or backup subsystem inactive for maintenance.*(4)

*For rationale, refer to specified numbered item in Section 7.2.5

7.2.4 Major Interfaces

Interface requirements, in addition to those covered in Section 2.2, are included in the following sections.

Experiments Provisions

1. Atmosphere

   The OLS ECLSS shall provide atmospheric gas circulation capabilities to provide a shirtsleeve environment in all experiment areas that require human habitation.

   a. Pressurization, Depressurization, and Leakage

      Airlock experiments - Capabilities for pressurizing and depressurizing the airlock from an onboard assembly shall be provided. Airlock capabilities shall be as specified below:

Volume	200 cubic feet
Pressurization time	To be determined from operational considerations
Depressurization time	24 hours maximum
Frequency of use	Three times per year
Gas composition	Same as OLS

   b. Temperature control - The OLS shall provide temperature control between 65 and 75 F for integral experiments. Capability shall be provided in the experiments area to supply air selectable between 60 and 75 F. The OLS atmosphere shall accommodate 1000 watts of sensible heat maximum from the integral experiments. (Sized on the basis of 25 percent to the atmosphere of a maximum 4000 watts.)

   c. Pressure control - The OLS shall provide total pressure control and oxygen partial pressure control for experiments to the same condition as the OLS atmosphere. The OLS and experiments atmosphere shall be controlled to 14.7 psia (with variation to 10 psia allowable) and oxygen partial pressure at 3.1 psia. Experiment pressure requirements different from the OLS shall be provided by experiments.

d. Humidity control - The OLS shall provide atmosphere at 8 to 12 mm Hg partial pressure of water for integral experiments. Humidity control to a different level shall be provided by the experiment. Excessive experiment-caused humidity (greater than approximately 0.5 lb/hour or nonhuman water to the atmosphere) shall be removed by experiment facilities.

e. Contamination control - Toxic, corrosive, or bacteriological contaminants shall be removed by the experiments before the atmosphere is returned to the OLS system. The OLS contaminant control assembly may be utilized by experiments for the control of contaminants with maximum generation rates as specified in final report GDC-DAB-67-003, Vol. VI ECLSS, Study for BSM Preliminary Definition, dated October 1967.

2. Active Thermal Control

The OLS shall provide active temperature control between 65 and 75 F for integral experiments sufficient to accommodate 4000 watts maximum dissipation.

3. Water Management

a. Storage and/or generation capability for supplying 35 lb/day maximum of potable water shall be provided by the OLS ECLSS. The water shall have the same potability and purity requirements as the OLS (NASA/MSC specification PF-SPEC-18, Command Module/Lunar Module Potable Water Specification, 25 June 1969).

b. Experiment water requirements with a different purity requirement shall be considered an experiment expendable item and handled as a logisitics supply material.

c. Experiment water which cannot be accommodated by the OLS distillation reclamation assembly because of unusual chemicals or contaminants shall be considered a waste product and treated as a logistics return material. Water makeup for such waste water shall be treated as an experiment logistics supply item.

4. Waste Management

The OLS ECLSS shall provide capability for processing either individually or collectively a total of 30 lb/month of waste and trash materials from experiments.

5. Hygiene - Not applicable

6. Food Management

Preparation of all special human, plant, or animal nutrients shall be provided by the experiment. The ECLSS shall provide crew food storage and preparation capabilities. Any special freezer, refrigerator, and oven requirements shall be provided by the experiments.

Reaction Control Subsystem

The RCS shall supply storage of subcritical N_2, O_2, and H_2 sized to the following for ECLSS:

ECLSS Function	Representative OLS	Derivative OLS
Leakage	O_2 - 1247 lbm	O_2 - 2394 lbm
	N_2 - 3096 lbm	N_2 - 6894 lbm
Repressurization (20K ft^3)	O_2 - 350 lbm	O_2 - 350 lbm
	N_2 - 1150 lbm	N_2 - 1150 lbm
Sabatier Unit	H_2 - 324 lbm	H_2 - 324 lbm

The above requirements are based on 180 days storage capacity. For a detailed development of these requirements see the Reaction Control Subsystem sections of Volume V.

Environmental Protection Subsystem*(19)

1. ECLSS shall maintain a mean internal radiant temperature of 70 F nominal, 65 F minimum, and 75 F maximum.

2. The station atmosphere dew point temperature shall not exceed 57 F maximum. No condensation shall be allowed to form on internal surfaces.

Electrical Power Subsystem

The ECLSS shall interface with electrical power as follows:

1. 120 to 208 volts ac 400 Hz

2. The ECLSS assembly power load is:

*For rationale, refer to specified numbered item in Section 7.2.5

ECLSS Assembly	24-hour Average (watts)	Emergency (watts)
Atmospheric storage	350	0
CO_2 management	3090	650
Atmospheric control	2300	1283 (temperature/ humidity fans, monitor)
Active thermal	335	235 (pumps and heat exchangers)
Water management	837	0
Waste management	70	25 (toilets, urinals)
Hygiene	180	0
Food management	630	0
Special life support	0	0
Total	7792	2193

Note: Above power values are continuous; emergency loads are for a 2 to 30-day emergency.*(20)

Docking Provisions

1. Docking provisions will require that the docking port wall temperature is above the dew point prior to pressurization.

2. The ECLSS shall be supplied with the following interfaces:

   a. Attach points and clear area for personnel access with blower and ducting to supply the crew life support environment.

   b. Provisions for those docking ports which support the experiment module as follows:

      (1) Fluid couplings for water delivery and return

      (2) Coolant loop couplings and heat exchanger

      (3) Provisions for gaseous O_2 supply

*For rationale, refer to specified numbered item in Section 7.2.5

(4) Provisions for O_2, N_2 pressurization supply

(5) Provisions for air circulation

(6) Provisions for pumpdown capability

Crew Habitability

1. Atmosphere

The cabin atmosphere shall consist of an oxygen/nitrogen mixture at a normal operating pressure of 14.7 psia but capable of operating at selected pressures between 10 psia and 14.7 psia. The atmospheric total pressure so provided will maintain the partial pressure of oxygen in the alveolar spaces of the lungs between the limits of 100 mm Hg to 120 mm Hg. The various oxygen/nitrogen mixtures necessary to provide a partial pressure of oxygen of 3.08 psi and an alveolar partial pressure of oxygen of 100 mm Hg for cabin atmospheres ranging from 14.7 to 10.0 psia are as follows:

Oxygen (Percent)	Nitrogen (Percent)	Cabin Pressure (psia)
20.9	79.1	14.7
21	79	14.65
22	78	14.0
23	77	13.4
24	76	12.8
25	75	12.3
26	74	11.8
27	73	11.4
28	72	11.0
29	71	10.6
30	70	10.25
30.9	69.1	10.0

Carbon dioxide tensions on the OLS shall be maintained below 7.6 mm Hg in all habitable areas. The atmosphere constituents, including harmful airborne trace contaminants, shall be identified, monitored, and controlled in each pressurized compartment of the OLS.

In the event of OLS pressure hull damage resulting in pressure decay in a pressure volume, the duration of acceptable crew performance shall be considered to be that period of time until a partial pressure of oxygen of 1.9 psi is reached.

Facilities shall be provided for prebreathing 100 percent oxygen, for preconditioning a crewman prior to IVA/EVA operations.

2. Temperature

The capability shall be provided to maintain the temperature nominally between 65 F and 75 F in habitable regions of the OLS. Selective (independent) temperature control, on an area basis, shall be provided.

The temperature of interior exposed surfaces with which a crewman may come in contact shall not be less than 57 F for both metallic and nonmetallic surfaces nor more than 105 F for both metallic and nonmetallic surfaces.

3. Humidity

The water vapor partial pressure shall be maintained between 8 to 12 mm Hg, and no condensation shall form on internal surfaces.*(8)

4. Air Velocity

Air velocity shall be maintained between 15 feet per minute and 100 feet per minute, with 40 feet per minute as the nominal ventilation flowrate. The capability shall be provided to adjust the flowrate for crew comfort.

Auxiliary ventilation for localized cooling and comfort shall be provided, with both ventilation flowrate adjustment and selectable directional flow for certain areas.

5. Odor Control

Provisions for odor control shall be provided within each pressurized compartment of the OLS.

6. Contamination Control

Microbiologically and bacteriologically contaminated waste material shall be disinfected as close as possible to its source prior to storage, processing or disposal.

The concentration of bacteria within the atmosphere and within each of the pressurized compartments containing crew quarters, process laboratories, or experimental facilities shall be monitored and controlled by appropriate means.

*For rationale, refer to specified numbered item in Section 7.2.5

7. Metabolic Criteria

The following specifies metabolic criteria for light activity in a shirtsleeve, 14.7 psia (20.9 percent oxygen, 79.1 percent nitrogen) environment and shall be used for design purposes:

Metabolic load (nominal) - 11,900 Btu/man-day, equivalent to 3000 kcal/man-day

Oxygen consumption (nominal) - 1.84 lb/man-day

Carbon dioxide production (nominal) - 2.25 lb/man-day

Water balance (nominal) - 7.10 lb/man-day

Average metabolic rates for various activities are as follows:

Sleeping	280 Btu/hour
Eating	450 Btu/hour
Working (light activity)	600 Btu/hour
Exercise (moderate to heavy)	1600 Btu/hour
Recreation (relaxation)	400 Btu/hour
Personal hygiene activities	465 Btu/hour
EVA/IVA (suited/ pressurized)	1200 Btu/hour

8. Water

Sufficient potable water shall be provided for the crew to maintain water balance. Potable water requirements in pounds per man per day, based on a metabolic load of 11,900 Btu per man per day, are included in Table 7-6.

Sufficient water shall be provided for washing and cleaning to satisfy the following requirements:

Crew washwater - 4.0 pounds/man-day

Crew shower water (based on two showers/man-week at 17.2 pounds of water/shower) - 4.9 pounds/man-day

Dishwashing/housekeeping - 3.0 pounds/man-day

Laundry - 4.0 pounds/man-day

Hot water (155 degrees F ± 5 degrees F) and cold water (50 degrees F ± 5 degrees F) shall be provided in sufficient quantities for crew usage in both personal hygiene areas and food preparation areas.

Table 7-6. Potable Water Requirements

Human Water Balance	Cabin Pressure	
	14.7 psia	10.0 psia
Water gain		
Water of oxidation (from food)	0.78	0.78
Beverages plus water in food	6.32	6.47
Totals	7.10	7.25
Water loss		
Insensible (lungs + latent)	2.44	2.69
Sensible (perspiration)	1.06	0.96
Urine	3.45	3.45
Water in feces	0.15	0.15
Totals	7.10	7.25

The capability shall be provided for mixing hot and cold water in a suitable ratio so as to provide water at a temperature comfortable for crew washing and showering.

9. Food Preparation, Preservation, and Storage

   The equipment ncessary to prepare, preserve, and serve the food required to satisfy the crew nutritional needs shall be provided.

7.2.5 Rationale

1. NASA specified for Earth Space Station. Based upon earth sea level PPO_2.

2. Metabolic rates are based upon crew work loads. (See Crew Habitability section.) The crew exchange of 16 days is from mission analysis and sequencing of the OLS.

3. The leakage rate is based on the docking port requirements of the representative and derivative OLS configurations with the experiment airlock and EVA hatch(es). Seal length was used to ratio actual Apollo leakage. The leakage was not corrected for pressure difference. (The same method was used on the Earth Space Station.) See Section 6.0 for docking port requirements and also Volume V for configuration definition.

4. See Section 5.0, rationale numbers (8) and (13).

5. Ranges are in the general comfort area and were NASA selected for the Earth Space Station.

6. Because personal comfort varies among the crew, individual selective temperature control is required. Selective temperature control does complicate the ECLSS design.

7. A pressure of 14.7 psia avoids any unknown long-term effects of lower pressures and allows earth-based controls for lunar experiments. The 10-psia deviation is allowed so that equipment failure resulting in slow leakage increase or other pressure decreasing failures will not define an emergency before repair can be accomplished. Also, allowing pressure decay will enable the oxygen for leakage makeup to be used metabolically in an emergency.

8. These various numbers are based upon human comfort criteria ranges.

9. To prevent electrical shorting, bacteria growth, etc., condensation must be prevented.

10. Thresholds are based upon 8-hour workdays for literature reported contaminants. Thus, following the standard policy of previous space vehicle studies, a conservative limit of 0.1 of the threshold limit is used.

11. The lower heat sink temperature limit of 40 F is based upon use of a water loop which must be kept above 32 F.

12. These numbers consist of experimental and analytically generated data developed for the Earth Space Station.

13. Same as the requirements for Skylab and Earth Space Station.

14. Reclamation of fecal water is not justified based upon the complex requirements for recovery and the amount of water contained therein.

15. Condensable wastes may coat the OLS surface and interfere with thermal coatings and other systems. Solid wastes will interfere with vehicle operations because they would be in approximately the same orbit.

16. Prevents transport of contaminated materials over long distance, which could cause vehilce contamination.

17. In case of pressure volume loss, a shower is still available.

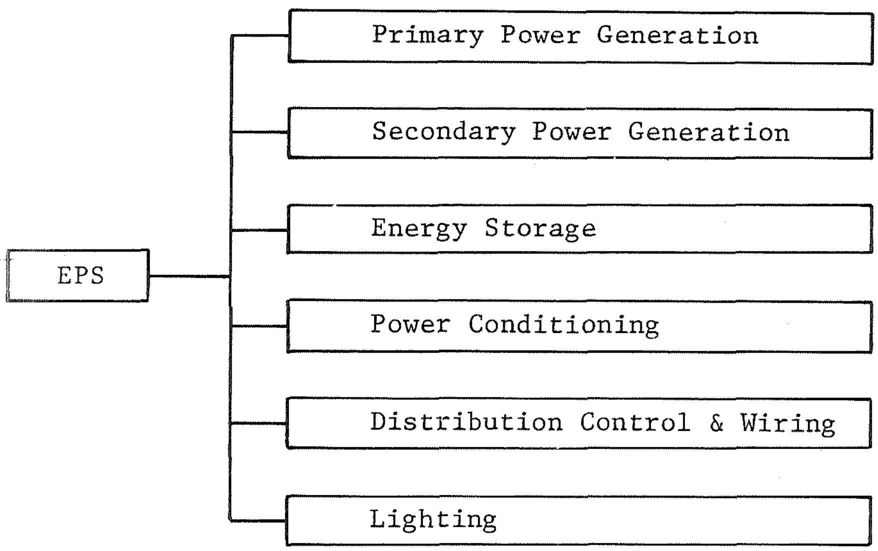
18. These requirements were developed from the Earth Space Station and the functional requirements.

19. These requirements essentially establish the major interfaces between ECLSS and thermal protection and usually provide the major driver to the passive thermal/structural design (e.g., insulation, thermal conductance control of structure, coatings, etc.)

20. See Section 5.0, rationale number (15).

7.3 ELECTRICAL POWER SUBSYSTEM

The primary function of the EPS is to provide continuous electrical service. To accomplish this, the EPS shall generate, regulate, condition, store, control, and distribute electrical power required for the full duration of the OLS life, including power for backup and emergency contingencies. Besides power distribution, the EPS shall provide for the general lighting (interior and exterior) and the sequential mechanization (ordnance devices, power switching, etc.) needs of the OLS. In addition, the EPS shall be capable of transferring power to peripheral equipment, lunar landing vehicles, and docked logistics vehicles (cislunar tugs, etc.). Major EPS functions are summarized below:



7.3.1 Functional Requirements

Major Power Modes

The EPS shall be functionally capable of operating under the major power modes as described below.

1. Unmanned Launch and Premanning Power. Power shall be supplied by a source other than the primary power source.*(1)

2. Manned Earth Orbit (EO) Operations. Power shall be supplied by the primary power source during earth orbit manned checkout, cargo transfer, and RCS docking operations.*(2)

3. Unmanned EO and Translunar Flight. Power shall be supplied by the primary power source during unmanned earth orbit, translunar flight and lunar orbit (prior to crew boarding) mission phases.

4. Initial Manned Lunar Orbit (LO) Operations. Power shall be supplied by the primary power source during manned checkout in lunar orbit.*(2)

5. Manned Normal Operations. Power shall be supplied by the primary power source during normal operations in LO.*(2)

6. Manned Backup Power Operations. Power shall be supplied by the primary power source with a reduced capability.*(2,3)

7. Manned Emergency Power Operations. Power shall be supplied by a special emergency source, the unmanned launch and premanning power source, or a portion of the primary power source or combinations thereof. But whichever source is selected, the emergency source shall never be compromised (during operations) to the extent that it is not always in a condition to take over and provide the required emergency power.*(4)

8. Lunar Orbit Quiescent Storage. The EPS shall have the capability of supplying power from the primary source during quiescent storage in lunar orbit.

9. Earth Eclipse. An emergency auxiliary power source shall supply power during an earth eclipse.

10. Solar Flares. During major solar flare events the emergency/auxiliary power source shall supply power.

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*For rationale, refer to specified item number in Section 7.3.5

Major Mission Power Phases

The power source(s) for each mode during the major mission phases are identified in Table 7-7.

Table 7-7. Major Mission Power Phases

Mission Phases	Primary Power	Backup Power	Emergency/ Auxiliary Power
0. Prelaunch	GSE	-	-
1. Ascent to orbit	-	-	X
2. Premanning	-	-	X
3. Manned EO operations	X	X	X
4. Unmanned EO, TL flight	X	X	X
5. Initial manned LO operations	X	X	X
6. Routine operations	X	X	X
7. Manned emergency operations	-	-	X
8. Lunar orbit quiescent storage	X	-	-
9. Earth eclipse	-	-	X
10. Solar flares	-	-	X

Power Distribution

The EPS shall provide fixtures, controls, and wiring for the general and supplementary interior illumination requirements of the OLS.*(6)

Lighting

1. Interior. The EPS shall provide fixtures, controls, and wiring for the general and supplementary interior illumination requirements of the OLS.*(6)

2. Exterior. The EPS shall later provide for OLS exterior illumination requirements. Low-level illumination shall be provided around the interior of the docking mechanism(s). These lights shall not blind the TV camera.*(6)

3. EVA. The EPS shall provide lighting for EVA operations. Sufficient EVA lighting shall be provided to illuminate the full periphery of the OLS (not necessarily entirely at one time). Fixtures shall be fixed, portable, or combinations thereof. However, if portable fixtures are selected, the design shall be such that lamps do not inhibit the movement of the crew or restrict EVA operations.*(6)

*For rationale, refer to specified item number in Section 7.3.5

7.3.2 Performance Requirements

Any differences between representative and derivative OLS EPS performance requirements will be noted.

Flight Envelope

The EPS shall be designed and sized for operations within the flight envelopes described below.

1. Earth Orbit. The earth orbit shall be 31.6 degrees inclination orbit at 258-n mi altitude with an atmosphere equivalent to the 1959 ARDC standard.*(7)

2. Translunar Flight. Depends upon the operational characteristics and trajectory of the cislunar shuttle.*(7)

3. Lunar Orbit. The lunar orbit shall be 90 degrees inclination at 60-n mi altitude. The flight mode shall be X-POP Y orientation.*(7)

Major Power Modes

The EPS shall be capable of supplying power for the power modes described below. The major factor accounting for the differences between representative and derivative OLS power requirements is the modular mission concept.

1. Unmanned Launch and Premanning.

   On the representative OLS, the EPS shall be capable of supplying 2 kw of continuous power to the loads for a period of up to 5 days from launch (up to EO crew broading).

   On the derivative OLS, the EPS shall be capable of supplying 100 w of continuous power to core module 1A for a period of up to 5 days prior to mating with the power module. When the power module and C1A are mated, the EPS shall supply 2 kw for 20 minutes for solar array deployment and system checkout.*(8)

2. Manned EO Operations.

   The EPS shall be capable of supplying the represenative OLS with an average of 13.5 kw to the loads with a sustained load at any one time of 15 kw for a period of up to 2 days for preliminary cargo transfer, onboard checkout operations by the checkout crew, and rendezvous and docking with the RCS.*(9)

*For rationale, refer to specified item number in Section 7.3.5

The EPS shall be capable of supplying 2.5 kw for 1 day to the derivative OLS. All the modules which comprise the derivative OLS configuration are not assembled in EO at the same time. The complete buildup is accomplished in lunar orbit and consequently, only partial subsystem checkout is performed in EO.

3. Unmanned EO and Translunar Flight.

   The EPS shall be capable of supplying an average of 5.5 kw to the loads with a sustained load at any one time of 8.0 kw for a period of up to 7 days during TLF and lunar orbit premanning operations on the representative OLS.*(10)

   The EPS shall be capable of supplying the derivative OLS with 2.5 kw for up to 7 days (including 3 days of checkout). Only a partial complement of derivative OLS modules will be assembled on the first CLS flight, hence the lower power requirements.

4. Initial Manned LO Operations. The EPS shall be capable of supplying an average of 15,000 watts to the loads of the representative OLS with a sustained load at any one time of 20,000 watts for a period of up to 2 days for additional cargo transfer, onboard checkout operations, and station activation by initial crew.*(11) The same power requirement holds for the derivative OLS but for the 16-day lunar orbit layover period of the CLS. This is the buildup and complete subsystem checkout period of the derivative OLS.

5. Manned Lunar Orbit Operations. The EPS shall be capable of supplying an average of 20,000 watts to the loads with a sustained load at any one time of 30,000 watts.*(12) Identical requirements for both representative and derivative OLS.

6. Manned Backup Operations. The EPS shall be capable of supplying an average of 13,500 watts to the loads for a minimum of 90 days.*(12) Identical requirements for both representative and derivative OLS.

7. Manned Emergency Operations. The EPS shall be capable of supplying 4000 watts of continuous power to the loads for a period of up to 48 hours at any time during EO operations and up to 30 days during LO operations.*(12,13) Identical requirements for both derivative and representative OLS.

8. Lunar Orbit Quiescent Storage. The EPS shall be capable of supplying the OLS with 1.9 kw for up to one year of quiescent storage in lunar orbit.

*For rationale, refer to specified item number in Section 7.3.5

9. Earth Eclipse. The EPS shall supply the OLS with 15 kw for approximately 3.5-hour duration of an earth eclipse of the sun.

10. Solar Flare Events. During solar flare events, the EPS shall provide 10 kw of power for the duration of the event (up to 3 days).

Subsystem Electrical Load Requirements

The EPS shall generate, condition, and regulate electrical power for general distribution throughout the OLS. Unless otherwise specified, the quality of the power deliver shall be per MIL-STD-704. Any subsystem requiring power conditioning not consistent with the requirements herein, must provide that conditioning within that user subsystem.*(14)

Primary Power. Primary power shall be supplied redundantly in the form of regulated 400 Hz, 120/208 vac with a limited amount of regulated 56 vdc available.*(14)

Major Mission Phases

1. Prelaunch. The EPS checkout prior to launch will be performed with a checkout crew onboard using the onboard checkout equipment.*(15)

2. Countdown. External power will be supplied to OLS during countdown. At a predetermined time prior to launch, the OLS will go on partial internal power. The switchover will be provided within the OLS and activated by remote control.*(16)

Electrical Distribution

1. Line Losses. Electrical power shall be redundantly distributed to all system users. Line drop shall be per MIL-STD-704, with the exception of the dc voltage, which shall have a maximum voltage drop of 2.5 volts between the regulated bus and the loads.*(14)

2. Circuit Protection. Redundant circuit protection shall be provided for all critical electrical power distribution circuits. Protection devices shall be sized to match subsystem user requirements.*(4)

7.3.3 Operability

Reliability

1. Electrical power shall be provided for performing full or reduced operations as indicated on the following page.*(4)

*For rationale, refer to specified item number in Section 7.3.5

Number of Failures	Subsystem Effect
1	Normal capability - no measurable reduction in performance
2	Full capability for crew safety and biological experiments. This situation can allow loss of mechanical experiment but permits mission continuation (critical loads).
3	Full capability for crew safety. This situation can allow loss of mechanical and biological experiments and terminates the mission (emergency loads).

2. Redundant paths, such as fluid lines, electrical wiring, and connectors, shall be located, where practical and feasible, so that an event which damages one line is not likely to damage the other.*(4)

3. Buses shall have redundancy to meet all normal operations requirements.*(4,17)

Maintainability

1. Equipment requiring maintenance shall be designed such that EVA operations will be minimized.*(4)

2. Replaceable units shall be readily accessible with minimum disturbance of other units.

3. Replaceable units shall be designed to permit direct visual and physical access by pressure-suited crew with connectors and couplings provided for ease of removal/replacement. Precision elements will be provided with suitable guides and clocking devices to aid in replacement.*(18)

4. The EPS shall be designed so that normal maintenance may be performed without shutting down the primary power.*(17)

Useful Life

The subsystem shall be designed for a minimum operational life of ten years with a resupply of consumables and replaceable items of equipment. This operational life may be obtained through long-life design and in-place

*For rationale, refer to specified item number in Section 7.3.5

redundancy for critical equipment whose failure could disable the OLS or imperil the crew. Age-sensitive materials will be avoided or protected for minimum degradation. Consideration shall be given to state-of-the-art for material selection and related design characteristics (such that wearout will not degrade performance beyond acceptable tolerance(s)) within subsystem life-cycle requirements.*(10)

Environment

See General, Section 2.2.

Human Performance

See General, Section 2.2.

Safety

1. In case of a failure of the primary power source to provide power for normal operations, the backup power source will automatically assumed the backup electrical loads until the primary power source can be brought on line again. In case of failure of the primary and backup power sources, the emergency power source will automatically assume the emergency electrical loads for a period of up to 48 hours during EO operations and up to 30 days during LO operations. *(4,13)

2. The EPS together with the information subsystem shall provide the necessary electrical distribution and the hardware for control of the EPS from two separate and redundant control centers, one center in each pressure isolatable volume.*(3,4)

3. All circuits shall be provided with circuit protection devices. Circuit protection devices shall be resettable from the control centers.*(4)

4. Life support functions shall be capable of being electrically isolated from the general distribution functions through automatic load shedding of equipment not related to life support functions.*(4)

5. Electrical distribution panels shall be adequately enclosed or otherwise protected to minimize hazards to the crew and provide maximum mechanical protection for the electrical subsystem and components.*(4)

6. Cable runs shall be suitably enclosed or otherwise protected to minimize hazards to the crew and provide maximum mechanical protection for the conductors.*(4)

*For rationale, refer to specified item number in Section 7.3.5

7. Bus isolation shall be such that failure of one bus will not cause failure of another bus.*(21)

8. Equipment in pressurized areas that is required for personnel safety or mission continuation (critical functions) shall be capable of surviving, active or dormant, in a depressurized environment for a time period (to be determined) sufficient to ensure reestablishment of a pressurized atmosphere in a damaged volume. This time period shall in any case be for a minimum of 30 days.*(4,13)

9. The capability shall be provided to supply power to perform emergency operations for a minimum of 30 days (48 hours EO) with one pressure volume inactivated, isolated, and vacated because of an accident.*(4,13)

10. The capability shall be provided for the detection of time-critical malfunctions of the EPS or overloads on the EPS and the automatic switching to a safe mode of operation.*(4)

11. Redundant equipment, lines, cables, and utility runs in pressurized areas that are critical for safety of personnel or mission continuation shall either be located and routed in separate compartments (i.e., separated by structural wall) or be protected against fire, smoke, contamination, and over-pressure.*(4,21)

7.3.4 Major EPS Interfaces

Experiment Support

The electrical power subsystem shall have interfaces with and support requirements for experiments as follows: *(22)

> Average power of 4 kw; maximum sustained power demand of 6 kw for less than 1 hour with a frequency of occurrence of not more than twice in 24 hours; and peak power of 7 kw for a duration less than 1 minute, the frequency of occurrence shall not be more than twice per hour. Sequencing of operation of experiments shall be required to preclude a power demand in excess of the power allotted above.

Docking Provisions

<u>OLS and Docked Vehicle Interface</u>. The electrical interface between the OLS and all docked vehicles shall be common at the docking port and shall meet the requirements described in the following paragraphs:

*For rationale, refer to specified item number in Section 7.3.5

1. Two connections, each with a five-wire ac 400 Hz circuit capable of 4.0 kw at 120 to 208 volts. The fith wire shall be for structure ground.*(4,21)

2. Two connections for controls, including a redundant information subsystem interface.*(4,21)

3. When a vehicle or experiment is docked to the OLS for service, its ground system shall be transferred to the OLS Vehicle Ground Point (VGP) and shall not use the docked vehicle structure.*(4)

4. When a detached experiment or docked vehicle is on internal power with the OLS connected, the module power distribution shall be of such design that there is no possibility of power flow from the docked module power supplies to the OLS buses or vice versa.*(4)

5. Caution and warning functions required for monitoring of the docked vehicle will be provided to the OLS prior to energization of the power connection. Under no condition shall power be permitted on any wire of the docking interface connections during connection or disconnection operations.*(4)

Environmental Control/Life Support Susbsystem

1. <u>ECLSS Power Requirements.</u> ECLSS normal and emergency electrical power load requirements shall be as follows: *(25)

   a. 120 to 208 volts ac 400 Hz

   b.

ECLSS Assembly	Normal (watts)	Emergency (watts)
Atmospheric storage	350	0
CO_2 management	3090	650
Atmospheric control	2300	1283 (temperature humidity fans, monitor)
Active thermal	335	235 (pumps and heat exchangers)
Water management	837	0
Waste management	70	25 (toilets/urinals)

*For rationale, refer to specified item number in Section 7.3.5

ECLSS Assembly	Normal	Emergency
Hygiene	180	0
Food management	630	0 (food freezer)
Special life support	0	0
Totals	7792	2193

Note: Above power values are continuous average loads in watts; emergency loads are for a 2- to 30-day emergency.*(13)

2. EPS Cooling Requirements. The ECLSS shall provide temperature control for EPS heat sources.

Information Subsystem

1. ISS Power Requirements. The EPS shall provide redundant power to the ISS. The EPS shall provide emergency power as required for communications, display, control, data processing, and tracking.*(4,21)

2. EPS Control Requirements. The ISS shall provide redundant fully automatic protective and corrective controls, including problem-solving (fault diagnosis, load shedding/transfer, etc.) as well as normal controls and displays designed to relieve the crew of the burden of continuous system status monitoring. *(4,20)

Structures

1. Lighting Protection. Structures shall provide electrical bonding between vehicles and appropriate ground connections to protect the OLS while mated to the launch vehicle on the pad at KSC against static electricity buildup and lighting surges.*(4)

2. Harness Ducts. Redundant primary power and electrical harness ducts shall be provided for distribution of power throughout the OLS, including the pressure bulkhead feed-through plates.*(4,20,21)

3. Heat Dissipation. Electrical cable runs shall take full advantage of the OLS structure for heat dissipation. Cable troughs should be designed to afford maximum heat transfer.*(23)

*For rationale, refer to specified item number in Section 7.3.5

Crew and Habitability

The EPS shall provide fixtures, controls, and wiring to satisfy, as a minimum, the lighting requirements (foot-candles) listed in Table 7-8.*(6,24)

1. Electrical power shall be provided for one color television set in each crew stateroom.

2. Electrical power shall be provided for the crew-related recreation and entertainment equipment in the recreation area. The equipment and associated power requirements are as follows:

Item	Power (watts)
Movie projector	500
Color television	300
Tape deck	50

3. The following electrical power shall be provided for each PGA:

   a. 56 vdc - 2 amperes at the umbilical interface when the suit is in operation

   b. 250 watt-hours for battery charging of each PGA

4. Electrical power shall be provided for the field type X-ray in the medical treatment area. This shall require an average of 200 watts for operation.

5. The capability and electrical power shall be provided for recharging portable lights.

Reaction Control Subsystem

Electrical power shall be supplied on a demand basis to each valve, electric blower, and ignitor circuit. If fuel cells are used in the OLS, the RCS shall provide storage of 3697 pounds of oxygen and 533 pounds of hydrogen reactants for emergency power generation for 30 days.

7.3.5 Rationale

1. The primary power source will not be activated until in earth orbit for safety and/or technical reasons. For the derivative OLS, primary batteries will supply power prior to solar array deployment.

*For rationale, refer to specified item number in Section 7.3.5

Table 7-8. OLS Lighting Requirements (Foot-Candles)

Area	Overhead (1)	Supplementary Local (2)	Emergency (1)	Low Level (1)
Crew staterooms (6)	30	Desk 50 Bunk 50	5	0.5
Commanders and exp. Coordinator staterooms (2)	30	Desk 50 Bunk 50 Grooming 50	5	0.5
Primary galley	50	Work counter 50-70	5	0.5
Backup galley	10	Work counter 30	5	0.5
Primary dining	variable to 30 (3)	Eating surface 30-50	5	0.5
Recreation	variable to 30 (3)	30-50	5	0.5
Personal hygiene			5	0.5
Lavatories	30	50	5	0.5
Toilets	30		5	0.5
Showers	30		5	0.5
Exercise	30	-	5	0.5
Medical	Selectable 50 and 150	Work counter 50-70	100 diffused 500 (4)	0.5
Work stations				
Maintenance/repair	30-50	Work counters 50-70	10	0.5
Experiment	30-50	Work counters 50-70	10	0.5
Control centers	variable 5-50		10	0.5
Airlocks	30		5	0.5
Aisles, passageways Tunnels-direct diffused	30			0.5

(1) Foot-candles are measured 30 inches above deck.
(2) Unless specified, intensities are measured at the surface of use.
(3) Variable lighting to 30 foot-candles may be designed with 0.5 foot-candle low limit to provide night light.
(4) Auxiliary diffused illumination of 500 foot-candles will be provided, automatically actuated in event of power failure.
(5) Diffused 500- to 1000-foot-candle lamp shall be located above the examination chair and be directionally adjustable in medical and dental area.
(6) Low-level lighting shall always be on except when emergency lighting is in use.

2. The earliest that the primary source will be activated is in earth orbit. Once activated, the primary source will be used for all mission modes (possible exception may be emergency mode). Safety considerations prevent nuclear power sources from being energized and technical reasons prevent solar array deployment prior to earth orbit. Once activated, nuclear power sources either cannot be deenergized (as in the case of radio isotopes, or it is highly undesirable (as in the case of reactors). Although by proper design solar arrays may be retractable, reliability considerations would favor keeping the solar array deployed.

3. Backup power is required for safety considerations and for mission continuation.

4. This requirement is necessary for crew safety considerations.

5. Power distribution is a function of the EPS.

6. Lighting requirements have been included as a function of the EPS on the space station and hence, on the OLS. General lighting requirements for the OLS are similar to those of the space station, including the requirements for docking mechanism(s).

7. Rationale for orbital characteristics and OLS flight modes can be found in the Orbit Determination, Section 2 of Volume II.

8. Although the premanning requirements are only 2 kw, the launch requirements (RCS) are additive, thereby resulting in a higher value. (Refer to Table 7-9) See Volume V for further discussion of derivative OLS requirements.

9. This requirement results when manned plus additional power for checkout/use of OLS equipment is required.

10. The increase over premanning power is caused by battery charging and an increase in ISS requirements. (Refer to item 7 for flight duration rationale.)

11. Required power is based on the assumptions that the initial crew consists of eight men and all loads will not be energized simultaneously. (Refer to item 7 for flight duration rationale.)

12. The power required is based on the electrical load analysis shown in Table 7-9.

Table 7-9. OLS Electrical Load Analysis**

Subsystem/Equipment	Sustained*	Average	Backup	Emer-gency	Premanned
CO_2 management	5,120	3,090	3,090	650	0
Atmospheric storage	600	350	60	0	0
Atmosphere control	2,300	2,300	2,300	1,283	210
Thermal loop	335	335	335	235	235
Water management	984	837	837	0	258
Waste management	1,700	70	70	25	0
Hygiene	1,540	180	180	0	0
Food management	4,500	630	630	0	300
Special life support	500	0	0	0	0
Total ECLSS	17,579	7,792	7,502	2,193	1,003
Communication/tracking	2,409	1,810	721	310	310
Data management	1,165	977	501	255	255
Display and control	1,880	1,155	650	350	0
Total ISS	5,454	3,942	1,872	915	565
CMG's	1,370	470	470	0	0
Navigation	304	139	128	98	34
IMU	198	161	161	198	198
RCS control	0	2	2	2	40
Landmark tractor	80	40	40	40	40
Total G&C	1,952	812	801	298	312
RCS	554	5	5	5	5
Lighting	3,600	2,400	1,000	500	25
Experiments	6,000	4,000	800	0	0
Total electrical loads (less EPS and distribution losses)	35,139	18,951	11,980	3,911	1,910

*The sustained load represents a feasible load that can be applied for up to 1 hour duration and not more than twice in a 24-hour period.

**See also Volume V, EPS section

13. Duration of the emergencies has been established with crew safety as the prime consideration and depends upon the logistics spacecraft characteristics. See Rationale no. 15 in Section 5.0.

14. The development costs of hardware for the OLS can minimize the qualification expense of hardware for the space station and the space base if the subsystem requirements can be met with common hardware. To obtain the benefit of common development costs, the space base voltage, frequency, and power quality were selected.

15. This requirement is in response to requirement 38 of the OLS guidelines.

16. External power is used as long as possible to reduce drain on the batteries/consumables.

17. This requirement is in response to requirement 12 of the OLS guidelines.

18. This requirement is in response to requirement 15 of the OLS guidelines.

19. This requirement is in response to requirement 4 of the OLS guidelines.

20. This requirement is in response to requirements 18 and 36 of the OLS guidelines.

21. This requirement is in response to requirement 16 of the OLS guidelines.

22. Based on the OLS experiment support requirements.

23. Use of the OLS structure for heat dissipation will reduce the heat rejection requirements of the ECLSS.

24. This requirements is in response to requirement 17 of the OLS guidelines.

25. Power required by the ECLSS is based on an 8-man crew size.

7.4 INFORMATION SUBSYSTEM

The OLS information subsystem (ISS) shall provide the effective acquisition, processing, storage, management, display, distribution, and analysis of data. It serves mission planning and operations scheduling, command and control, checkout, monitor and alarm, configuration control, inventory control, flight control, data management, support between OLS subsystems, the earth-based network, data relay satellites, lunar surface operation, experiment support subsystems, experiments, detached and attached modules or spacecraft and the crew-using communications, data processing, displays and controls, tracking, software, and special purpose support equipment.

7.4.1 Functional Requirements

The information subsystem shall provide the functions described in the following paragraphs.

External Communications

External communications shall be provided for the exchange of intelligence between OLS systems and crew and the earth data relay satellites, subsatellites, lunar surface, EVA crewmen, and other operational spacecraft in cislunar orbits.

Internal Communications

The internal communications function shall provide the intercommunication of intelligence between compartments, subsystems, integral experiments, IVA, attached spacecraft, and control centers and to the external communication function. The intelligence consists of voice, audio alarms, video, and public address as well as operations, maintenance, experiment and text type data. Control and display signals, portable life support subsystem data, and audio-video information functions are required.

1. Audio Entertainment and Paging

   The capability of listening to recorded music or other entertainment shall be provided. The audio entertainment function shall not prevent or delay paging, audio alarms, and general announcements.

2. Audio-Video Distribution

   Voice communications and closed-circuit video distribution shall be provided.

3. Digital Data Distribution

   Digital data distribution shall be provided within the OLS.

4. Peripheral Group

   Terminal units, switching and control logic, recording, input-output, and audio-video units shall be provided.

Tracking

Tracking functions of acquisition, trajectory determination, integration, and beam pointing shall be provided by the ISS.

Display and Control

Display and control functions shall be provided to perform flight management, operations management, planning and scheduling management, and experiment management. Display and control functions shall provide maintenance, repair, replacement, and servicing information. For all crew safety items, alternate displays and controls shall be provided.

Data Processing

Data processing functions shall acquire, process, distribute, and store data.

Software

Software shall be provided for all computer programs used to operate the information subsystem.

7.4.2 Performance Requirements

The information subsystem shall be modular in construction. Provision shall be made in the original design to provide for planned station expansion with no appreciable interruption of service. The information subsystem shall be compatible with and provide access to the earth complex and other lunar exploration program elements. Any differences between representative and derivative OLS ISS performance requirements will be noted.*(1)

External Communications

External commmunications shall provide communication links between the OLS and earth orbital and ground elements and between the OLS and other lunar program elements. Continuous voice communication with elements not in line-of-sight is not required. Use of data relay satellites will provide continuous capability. Capability to communicate with and obtain biomedical and portable life support subsystem data from EVA crewmen shall be provided.

1. Channels

   Five coherent duplex channels shall be provided for communications and tracking. Each channel shall have a capability of a 6.5-mHz baseband composite that can be configured to multiplex a variety of ranging, voice, videc, digital, and analog data forms. All channels may be operated concurrently.

*For rationale, see specified numbered item in Section 7.4.5

2. RF Frequency Allocation

Compatible with overall space operations. For the purposes of this report it will be assumed that the OLS operates on S-band frequencies.

3. Transmit and Receive Modes

Compatible with overall space operations.

4. Mission Phase Utilization (Transmit and Receive)

Table 7-10 lists the RF communications between OLS and earth as a function of mission phase.

Table 7-10. RF Communications Between OLS and Earth

Communication Mode	Mission Phase					
	Prelaunch (Checkout Only)	Launch and Ascent to Orbit	Premanning	Initial Manning	Initial Manned Operations	Routine Operations
Voice	X	-	-	X	X	X
TV	X	-	-	-	X	X
Experiment data TM	-	-	-	-	-	X
Subsystems TM	X	X	X	X	X	X
Computer data	X	-	-	X	X	X
Command	X	X	X	X	X	X
Text	X	-	-	-	X	X
Graphic material	X	-	-	-	X	X
Tracking	X	X	X	X	X	X
PRN ranging	X	X	X	X	X	X

Internal Communications*(2)

1. Internal Communications Information Sources

A list of information sources is included in Table 7-11. The source quantities specified in the table indicate the approximate number of input and output points that shall be provided and not the number of user devices (telephones, etc.).

Table 7-11. Information Sources

Item	Source and Bandwidth					
	Primary Private Voice Comm.	Backup Voice Intercom.	Video Camera	Video Monitor	Digital	Public Address, Speakers, and. Intercom.
Location	4 kHz	4 kHz	4.5 mHz	4.5 mHz	1 mBs	10 kHz
Experiment provisions	3	3	3	3	3	3
Docking ports	1	1	1	1	1	1
Airlock laboratory	1	1	1	1	1	1
Prime control center	2	1	1	5	10	1
Backup control center	1	1	1	3	5	1
Wardroom	1			1	1	1
Galley and dining	1			1		1
Repair and maintenance	1	1	1	1	1	1
Medical area	1		1	1	1	1
Staterooms (8)	8			8	1	8

*For rationale, see specified numbered item in Section 7.4.5

2. Entertainment and Paging Distribution

Entertainment and paging shall be carried over a single channel to all audio-video units. Normally, recorded music and TV shall utilize this channel under control from the primary control center. Discretionary station-wide paging shall be performed on the same channel. Audio alarms shall be transmitted on the line upon command from the monitor and alarm program and shall bypass all volume controls and ON/OFF switches. Verbal warning messages shall be handled through this alarm channel under operator option.

3. Audio-Video Distribution

Private voice communications shall be provided to each dining area, stateroom, control center, recreation center, and work station throughout the OLS. Nonprivate (intercom) backup voice communications shall also be provided between critical locations. A closed circuit video net shall be provided for operations support, experiment support, entertainment, and safety. The audio-video network shall have terminals for docked vehicles and attached modules.

4. Digital Data Distribution

The digital data distribution network shall link all data sources and loads within the OLS except for certain dedicated links between subsystems. Data collected from all sources including display and control, maintenance/repair, and experiments/operations shall be distributed by this network to the correct destinations. Digital data received by the external communications and docked vehicles also shall be handled in this distribution network.

5. Mission Phase Utilization (Data Distribution)

Table 7-12 lists the following performance requirements that the ISS shall meet during the listed mission phases.

Tracking *(3).

Tracking shall perform the function of beam pointing and shall determine direction, distance, and rates of acquired cooperative targets. The tracking function shall be integrated with the external communication function.

1. Beam Pointing

Capability shall be provided to point the beam(s) within 3 db beamwidths. Upon acquiring a cooperative signal, automatic tracking shall be provided.

*For rationale see specified item number in Section 7.4.5

Table 7-12. ISS Performance Requirements

	Mission Phase					
	Prelaunch (Checkout Only)	Launch and Ascent to Orbit	Premanning	Initial Manning	Initial Manned Operations	Routine Operations
Paging	X	-	-	-	X	X
Audio alarm	X	-	-	X	X	X
Entertainment	X	-	-	-	X	X
Audio intercomm.	X	-	-	X	X	X
Telephone	X	-	-	X	X	X
Video	X	-	-	-	X	X
Subsystems digital data	X	X	X	X	X	X
Experiment digital data	X	-	-	-	X	X
Up-link command data	X	X	X	X	X	X
Onboard cont/disp.	X	-	-	X	X	X
Text-type data	X	-	-	-	X	X

2. Ranging

The information subsystem shall be capable of returning PRN ranging signals to the ground complex or an interrogating vehicle. The information subsystem shall be capable of determining distance, direction and rates of detached modules, and other vehicles at medium range. Medium range is defined as from stationkeeping to OLS sphere of influence (1000 feet to 450 n mi). Short-range (stationkeeping to hard dock) tracking shall be accomplished by the guidance and control subsystem. Table 7-13 lists the ISS capabilities. *(4)

* For rationale, see specified item number in Section 7.4.5

Table 7-13. ISS Range Capabilities (With Reference to OLS)

Range	Position Uncertainty With Reference to OLS	Range Rate Uncertainty With Reference to OLS	Area of Coverage
Over 450 nmi	Degraded	Degraded	Spherical
450 nmi to 20 nmi	± 3000 ft spherical	0.5 ft/sec	Spherical
20 nmi to 1000 ft	± 500 ft radial (± 1 deg)	0.05 ft/sec	120-degree cone(1)
(1) Full cone angle centered on sides with docking ports.			

Display and Control

Display and control devices shall be provided to perform flight management, operations management, planning and scheduling management, and experiment management.

1. Flight Management Displays and Control *(5)

   There shall be sufficient information provided to a single position in the primary control center for overall cognizance of relative positions and rates and for active flight control of all vehicles within the OLS sphere of influence. Backup capability shall be provided in the experiment control center.

2. Operations Management Display and Control

   Operations management shall be performed at a single position. Backup capability shall be provided in the experiment control center. There shall be sufficient information provided to perform the following operations management functions, but not necessarily simultaneously, at the same position:

   a. Subsystem management - Information for subsystem (including docked modules) status and surveillance shall be provided at a single position. OLS and experiment subsystem remote control capability shall be provided.

   b. Maintenance - Information shall be available for coordination of OLS (and other LEP elements) checkout and maintenance. Displays, controls, and intercommunications shall be provided at this position for determining the degree of success of any maintenance.

* For rationale, see specified item number in Section 7.4.5

c. Emergency management - Criteria and information shall be presented to the commander/duty officer to enable analysis-evaluation of the nature and magnitude of any important problem. The data processing function shall perform detection and shall prepare caution and warning information for presentation to the commander/duty officer by display and control function.

d. Personnel management - Personnel activity and availability information shall be available. A list of tasks with priorities and personnel requirements also shall be available at this position.

e. Extravehicular activity - Visibility of and communications with personnel engaged in EVA shall be provided.

f. Inventory management - Sufficient information to decide on inventory item utilization shall be available. Inventory trend data for critical consumables shall be available.

3. Planning and Scheduling Management Display

There shall be sufficient information available at a single position to plan and schedule the maintenance, logistics-inventory, and personnel activities for the OLS and other program elements. The information display shall be flexible enough for crew personnel to decide which of the several plans and schedules to implement. Backup capability shall be provided.

4. Experiment Management Display

There shall be sufficient displays and controls provided at a single position (normally in the experiment control center) to manage and evaluate the experiments. The displays and controls for OLS support of experiment operations shall be provided at this position.

Three areas shall have display and control capability. In the primary control center, one position shall normally be utilized to perform the flight management function. The other position shall normally be utilized to perform OLS and other program elements operation management and planning and scheduling management functions. The experiment control center shall normally be utilized to perform experiment management functions. The display and control equipment in both control centers shall be physically identical in design and configured by software to the desired configuration. The commander shall be provided with sufficient displays and controls in his quarters to perform planning and scheduling management. Displays and controls shall consist of two types of equipment integrated into a single package. The annunciation (message) associated with each display and control shall be configured by software.

5. Display Types * (6)

The displays provided on each subassembly shall be identical in design and capability. The displays shall consist of the following:

a. Universal multiformat display - This device shall be capable of displaying any combination of alphanumeric, graphic, or pictorial information. All electronic circuitry required to drive, hold, extinguish, or perform logic selection shall be provided within the assembly. The data processing assembly shall provide the information to be displayed.

b. Hard data viewer - This device shall be capable of displaying microfilm-type material. The data processing assembly shall identify the specific frame to be retrieved.

c. Alphanumeric fixed format - This device shall be capable of displaying 15 lines of information at 50 characters per line simultaneously.

d. Numeric display - These devices shall be provided to display critical subsystems parameters. Parameter identification shall be accomplished through use of control function keys.

e. Hard text printer - This device shall be capable of providing reusable hard-copy documents. A capability shall be provided for a 96-character font, 48 characters per line, and 6 lines per inch.

6. Control Types * (6)

The controls provided on each subassembly shall be identical in design and capability. The controls shall consist of the following:

a. Discrete keyboard - This device shall be capable of inputing discrete commands. The annunciation and function of each key shall be software controlled.

b. Alphanumeric keyboard - This device shall be capable of inputting alphanumeric information.

c. Mode keys - These devices shall be capable of inputing discrete mode commands. The function of each key shall be software-controlled.

d. Special purpose controls - These devices shall be provided for those functions that cannot be controlled by a single series of discrete commands.

* For rationale, see specified item number in Section 7.4.5

e. Display address controls - These devices shall provide for the routing of information to any single or combination of display devices.

Data Processing

Data storage shall consist of acquisition, processing, distribution, and storage.

1. Acquisition

Data acquisition shall include the requirement of acquiring both soft and hard data. This includes the collecting, conditioning, and combining of data for subsequent data processing functions. The types of data involved include command-control, maintenance-repair, and experiment and program element support data and may be either analog or digital in nature. Hard data includes physical data, specimens, photographic film, and biological products.

Data shall be collected from the following sources:

a. OLS subsystems

b. Crew input through man-machine devices

c. OLS integral and attached experiments

d. Detached modules (cargo, propellant if detached depot is used)

e. Earth-based ground control or tracking facilities

f. Vehicles in near vicinity (including lunar surface) or docked

g. LSB

h. EVA

The conditioning process for soft data shall include the following:

a. Analog-to-digital conversion
b. Parallel-to-serial conversion
c. Time annotation

The conditioning process for hard data shall include the following:

a. Placing hard data in containers
b. Photo processing
c. Oscillograph processing
d. Image processing

The soft data shall be combined by either frequency division multiplexing or by time division multiplexing such that it is suitable for transferring onto the data buses.

The data processing assembly shall have access to all data through the internal communications data bus. Parameters shall be sampled on a selective basis, under program control, by having the computer address the desired test point. The requested data shall be converted (analog to digital) if required and routed to a computer input channel also under program control. All data points will not be sampled during each pass through the monitor program. Data required for diagnostic purposes is typical of test points that are not sampled each time, whereas data required for monitor-alarm and fault detection shall be required for continuous observation. Additionally, the sampling rate for the same parameter may vary depending upon the usage (i.e., the same test point may be common to both the monitor-alarm and fault isolation functions). During the fault isolation routine, the sampling rate may be greater than during the monitor-alarm routine. The information subsystem peak data acquisition rate shall be 10 megabits per second. Hard data shall be acquired by manual means.

2. Processing

The processing function shall provide the transfer function between the acquisition function and the distribution function. The specific operations to be performed include the following:

Receive transferred data
Separate mixed data
Route data within the assembly
Compress data
Analyze data
Edit data
Transfer data
Compute
Format

The computation function shall: (1) process data relative to the control of the OLS subsystem, experiment, detached module, or other vehicle in the vicinity; (2) process data required for mission planning and scheduling of operations and experiment activities; and (3) process and analyze data for anomaly detection and resolution.

Hard data processing shall be provided for photographic processing and image reproduction. The data processing assembly shall provide for soft data processing. The data processing assembly shall be general purpose digital computers connected in a multiprocessing scheme that is under control of a master executive program. The minimum processing capability under worst case failure and maintenance conditions shall provide command-control for subsystem management, maintenance, and emergency management. This minimum capability shall be provided in each pressurized volume. The data processing assembly shall have the following capabilities: * (7)

Full arithmetic capability with both fixed and floating point notation

Byte (8 bits) manipulation

Double precision arithmetic operations

An interrupt capability for internal and external interrupts and power interruption

Provide timing signals with a stability of 0.01 part per million

Provide for self-diagnosis

The computer word length shall be 32 bits

The data word byte shall be 8 bits

Perform up to 10 million equivalent-add operations per second (one equivalent-add operation requires two machine cycles)

Be capable of accepting data at a rate of up to 10 million bps

3. Distribution

Data distribution shall control the routing of the data to the appropriate terminal and for the data buses. For soft data, this includes distribution to the following:

a. OLS displays
b. OLS subsystems or other functional program elements for control purposes
c. Storage
d. Transmission link
e. Remote terminal units

* For rationale, see specified item number in Section 7.4.5

The distribution for hard copy shall include the following:

a. Packaging for transfer to earth or LSB
b. Distribution to OLS personnel for analysis

The data processing assembly shall deliver data and commands to the using peripheral equipments by addressing a specific remote terminal. Each remote terminal shall have the capability to store data or commands addressed to it. The medium used for transfer shall be the internal communications data bus. Commands will be decoded at the remote terminal and distributed to the user. Control, timing, and sequencing of stimuli generation shall be provided by the information subsystem. The stimuli required (function generation, calibration energy, and component insertion), if any, as a result of a command shall be generated by the user. The delivery rate to peripheral equipment shall be compatible with the user device. The maximum output data rate shall be equal to the maximum acquisition rate (10 megabits per second) and time-shared with it. Displays, hard-copy devices, audible alarms, storage devices, and RF links shall be considered as peripheral equipment. Hard data shall be returned to earth.

4. Storage

There shall be two basic types of storage of data: noncomputer and computer. The noncomputer data shall include texts, microfilm, photographic film, and experiment samples. The three classes of computer data storage shall be as follows:

a. Operating - Operating storage shall be the near-zero access time storage from which instructions are executed.

b. Mass - Mass storage shall be supplemental to the operating storage and have rapid access time.

c. Archive - Archival storage shall be the moderate access time off-line storage and shall be directly connected to and controlled by the computer.

Total operating memory for the data processing assembly shall have a storage capacity of 256K words (8 memory modules, 32K words per module). Each processor shall be allocated portions of operating memory consistent with task assignments.

The baseline ISS storage capability (excluding archival storage) shall be 2.5 megawords minimum. This storage shall be word-organized with nondestruct readout and of modular construction of 256K-word increments. It shall be capable of "read/write", "read only", and "write only" modes of operation.

The information subsystem archival storage transfer rate between processor and storage unit shall be one megabit per second minimum. The time required to retrieve specific data from the archive storage shall be similar to that of ground-based computers (i.e., minutes). There shall be a minimum of four such units (tape decks). Tape reel capacity shall be 1.25 x 10^8 words.

All storage modules and units shall be easily removable, transportable, and reinsertable without degrading the data contained therein. A suitable protective container may be utilized to fulfill this requirement. Other information subsystem storage requirements are as follows:

Television - 25 hours (4.5 mHz)
Music - 48 hours (10 kHz)
Voice - 2000 hours (4 kHz)
Text - 3 x 10^6 pages using microfilm

5. Instrumentation

The ISS shall be the integrator of all measurement requirements. Displacements, temperatures, pressures, etc., shall be converted to equivalent electrical signals within the subsystems. Commonality of instrumentation transducers and signal conditioners shall be a design goal.

Instrumentation shall include measurements for crew habitability, biomedical experiments, subsystem functional operation, checkout, and primary structure penetration, radiator, and sensitive surface degradation caused by meteoroids.

Instrumentation from subsystems includes sensor and signal conditioning at 0 to 5 volts d-c from a source impedance no greater than 500 ohms (initial sizing) before interfacing with the information subsystem.

Software

Computer programs from the OLS shall consist of all programs required to operate the information subsystem. These programs shall provide for the acquisition, processing, storing, retrieving, communications, and distribution of information and data to enable ground and flight crews to control and support the following:

OLS prelaunch, launch, earth orbital, TL flight, and lunar orbital operations

OLS vehicle interface operations

LEP missions support operations

Experiment operation/scientific investigations

In addition, the software shall consist of all computer programs required to modify, simulate, and verify the operational computer programs. A modular design concept shall be employed in software construction. Each program module shall be constructed to be verified readily. Capability shall be provided to permit in-orbit program modifications by selected crew members.

All computer programs developed for the ISS shall be classified as one of three functional types: (1) supervisory programs (operating systems), (2) application programs, or (3) support programs. The program operating memory utilization is shown in Table 7-14.

7.4.3 Operability

Reliability

1. External Communications

   Capability shall be provided such that external communications shall not be dependent upon one RF path to earth, EVA or free-flying vehicles.

2. Internal Communications

   Double-wire telephone and intercommunication shall be provided in redundant, physically separated wire runs for each pressure volume.

3. Tracking

   The tracking function shall still be provided following any one failure.

Table 7-14. Operating Memory Utilization

Tasks	Gross Words	Net Words
Continuous functions	87K	87K
Frequent functions	76K	
Average usage (70 percent)		53K
Batch functions	106K	
Operations (30 percent)		84K
Experiments and Backup		84K

4. Command and Control

   Command and control of the OLS experiments (including line of sight, free-flying experiment modules) shall be provided separately in each pressure volume and interlocked so as to prevent loss of critical functions.

5. Data Processing

   Active redundancy shall be provided for operations following any one failure. This capability shall be available in both pressure volumes of the OLS.

   Provisions shall be available for dual redundant primary power inputs and a power input for backup power.

Maintainability

See Section 2.2.

Useful Life

See Section 2.2.

Environment

See Section 2.2.

Human Performance

See Section 2.2.

Safety

1. The capability shall be provided to detect malfunctions in the operations of the subsystems and experiments using data provided by such subsystems and experiments, trace the malfunction to the failed in-flight replaceable unit, and display the information necessary for corrective action.

2. For those malfunctions and/or hazards that may result in time-critical emergencies, provisions shall be made for the automatic switching to a safe mode of operation and for caution and warning to personnel.

3. The capability shall be provided to monitor the status of EVA personnel by two independent means. These data shall be available at the control centers.

4. The capability shall be provided to determine the existence of emergencies, such as fires, toxic contamination, depressurization, structural damage, etc., using data provided by other subsystems and experiments. Appropriate caution and warning information shall be provided to affected crew members for such situations, informing them of the type and location of the emergency and of the necessary corrective action.

5. A backup control center shall be provided in different pressure volume from the primary control center. It shall have the capability (at the minimum) to:

    a. Provide the command and control functions to operate the active subsystems and experiments in the event of loss of access to the volume containing the primary control center due to an accident.

    b. Provide sufficient monitoring, checkout, command and control functions of the subsystems and experiments in the affected volume to ensure safety, prevent further damage to equipment, and determine repair, IVA maintenance, and resupply requirements to restore shirtsleeve access to the affected volume.

6. The OLS shall be provided with an override capability to exercise flight control over all vehicles in the lunar vicinity and on the lunar surface including stationkeeping and hard dock. The OLS control centers shall be capable of continuously monitoring and controlling closing ranges, rates, and attitudes to ensure structural integrity and crew safety during terminal rendezvous and docking operations.

7.4.4 Major Interfaces

Experiment Provisions

1. An experiment control center shall be provided having command and control and display capabilities. The experiment control center shall also serve as a backup control center for the OLS. Backup capabilities for the experiment control center shall be provided in the OLS primary control center.

2. The interface between the ISS and free-flying subsatellites shall be via RF link. The ISS shall provide commands, computer data, and ranging signals. The subsatellites shall provide, upon command, turnaround ranging signals, subsystem data, and experiment data. The interface between the ISS and docked subsatellites shall be via coaxial cables. This shall connect the digital data distribution bus to the subsatellite with suitable modems. The ISS shall be capable of supporting two subsatellites on station. The interface between the ISS and integral experiments shall be through remote acquisition and control units (RACU's) and/or

modems. The OLS information subsystem shall provide the command control capability, data acquisition, processing, storage, relay capability, display capability, and the checkout and fault isolation capability required to support all experiment functional program elements as outlined herein.

a. Data types

(1) Soft data may take the form of analog data, digital data, or television displays. The responsibility for digitizing and formating rests with the OLS information subsystem.

(2) Hard data includes physical data, specimens, photographic film, and tapes. The ISS shall maintain an inventory of hard data.

b. Data rate/quantity * (8)

(1) Digital - Instantaneous peak 6×10^6 bps
- Daily (maximum) 3.5×10^{11} bpd
- Daily (average) 1×10^5 bps

(2) Television - Station CCTV (2.9 - 4.5 mHz) 3 channels
Station to surface (4.5 mHz) 1 channel

(3) The ISS shall be capable of acquiring data from lunar orbiting subsatellites for distances up to line of sight.

c. Storage capability

Operating memory	18K words
Mass storage	1 megawords
Tapes	180 pounds
Hard copy	180 pounds

d. Command and control

Discrete commands	1500
Variable commands	80 eight-bit commands

The capability for command and control of lunar orbiting subsatellites shall be provided for distances up to line of sight.

* For rationale, see specified item number in Section 7.4.5

e. Displays

Types: Graphic display device. Provision is required for curve tracing and plotting.

Signal light

Meter

TV (includes closed-circuit TV)

f. Data processing capability - 1×10^{10} bpd

g. Timing - timing signals shall be provided for a stability of 0.01 part per million at a rate of at least 1 kHz.

Crew Habitability

The interface between the ISS and the crew and habitability subsystems consists of the capabilities described in the following paragraphs.

1. Alarms and Displays

   a. Audio (tone and voice) and visual (flashing light) alarm(s) shall be provided in all habitable areas. Audio alarms define the required crew action.

   b. ISS access displays shall be provided.

2. Communications

   a. Two-way intercommunications shall be provided between all habitable areas.

   b. Two-way hardline and RF communications capability shall be provided between the primary and backup control stations and crewmen performing EVA in pressure suits. Two-way hardline and (buddy system) communications capability shall be provided between the primary and backup control stations and crewmen performing IVA in pressure suits.

   c. The capability for private communications with earth shall be provided.

   d. The capability to receive and record selectable entertainment type audio and video communications (music and TV) shall be provided.

Guidance and Control

1. The guidance and control system shall make the following information available to the ISS for use in displays, for system management, and in support of onboard checkout:

   Subsystem status measurements

   Power and mode status

   Attitude, attitude error, rate, and delta V information

   CMG gimbal angles and rates

   Docking range and angles and associated rates

2. The following represents the types of guidance and control computations that shall be performed within the ISS data processing assembly:

   CMG desaturation requirements (time-to-saturation prediction)

   Current OLS attitude and rate and reference attitude alignment

   Position vector of targets of opportunity in LCI coordinates (tracked by astronaut using the G&C sextant-telescope)

   Current OLS estimated state vector (position and velocity, orbital elements)

   Lunar landing tug guidance parameters

   Experiment to G&C reference calibration data

   Guidance, targeting and delta V commands for rendezvous, docking, deployment, and station-keeping of free-flying vehicles

   Reaction jet commands and delta V prediction for OLS orbit maintenance

   G&C configuration status (real-time)

   G&C operation status (mode)

   Real time failure identification and maintenance/replacement requirements

Energy management computations associated with jet firings

Control modeling, parameter estimate and adaption

Star tracker pointing commands

State vector propagation and update for free-flying subsatellites, and vehicles and station-keeping and collision avoidance computations

3. The ISS shall make the following information available to the guidance and control in support of the previously mentioned computations:

Vehicle configuration

Sun and earth ephemerides

Star catalog

Range, range rate, OLS, and OLS rates from approach radars (for ranges greater than 1000 feet)

Scheduled initiation of station delta V's and CMG desaturation

Reaction jet attitude control inhibits and jet failure data

Crew interface - manual navigation sightings, operation mode commands, configuration commands, and maintenance-in-progress/accomplished data

Subroutines and bulk storage data loads

Permanent and temporary data storage

Experiment reference alignment

Maneuver schedule

Timing signal at 1-kHz rate

Docking Provisions

Docking provisions shall provide the following information capability at each docking port:

Mounting provisions for the connection of docked elements to the internal communication busses.

Transmission of up to three TV channels between the docked elements and the OLS

Two-way voice communication between the docked element and both the primary control center and experiment control center.

One data channel shall be used to perform a checkout of a docked element. The OLS internal computations and processing capability shall be used to monitor the docked elements subsystems and perform routine diagnostic exercises to verify element readiness for release from the OLS.

Reaction Control Subsystem

Status data shall be provided for all the propellant valves, engines, and propellant fans to determine their open-closed or on-off conditions. Selected propellant tank, propellant line, propellant accumulator, and engine package temperature and pressure data will be available to the ISS to facilitate the control and monitoring of the RCS. The information subsystem shall provide control commands and checkout commands based on the data provided by the RCS. The ISS alarm system shall advise the astronauts of any RCS anomaly. The information subsystem shall also keep an inventory of in-flight replaceable units. During a resupply mode, the information subsystem shall provide command signals to the cargo module to control the propellant resupply flow. The ISS shall provide a manual control capability for the RCS jets that overrides the automatic commands.

The interface between the ISS and the RCS shall be at the remote acquisition and control units (RACU). The RACU may be contained within an in-flight replaceable unit of the RCS subsystem.

The ISS shall provide commands to the RCS. All commands shall be low-level digital logic pulses.

Environmental Protection Subsystem

1. The environmental protection subsystem shall provide the following quantities and types of measurements (initial sizing attempt) to the ISS:

Type	Quantity
Operational	200
Additional fault isolation	210
Total analog	410

The ISS shall provide commands to the environmental protection subsystem. All commands shall be low-level digital logic pulses.

2. The solar storm shelter shall incorporate the backup command and control consoles to permit the crew to maintain the minimum required station operations during a major solar flare event.

Electrical Power Subsystem

1. ISS Power Requirements

   The EPS shall provide redundant power to the ISS. The EPS shall provide emergency power as required for communications, display, control, data processing, and tracking.

2. EPS Control Requirements

   The ISS shall provide redundant fully automatic protective and corrective controls, including problem-solving (fault diagnosis, load shedding/transfer, etc.) as well as normal controls and displays designed to relieve the crew of the burden of continuous system status monitoring.

7.4.5 Rationale

1. OLS systems requirements information subsystem (ISS) - The OLS/ISS requirements are adapted from those developed during the EOSS studies. Preliminary estimates indicate similar ISS requirements for both stations with major differences arising in software, planning and scheduling, and in the utilization of the longer range RF links. Essentially, similar link requirements exist for near space elements. The OLS link to a surface base resembles the EOSS link to an earth ground station and the EOSS link to a DRSS is roughly equivalent to the link from the OLS to an 85-foot MSFN station. The compatibility of requirements and the modular design philosophy imply a high percentage of commonality between EOSS and OLS equipments.

   Known potentials for growth in requirements include additional duplex channels and a tracking antenna for operation through lunar satellites. The modular construction requirement will preclude a major impact on most of the subsystem designs should this requirement become firm. However, the tracking antenna requirement could be a major item, depending upon the type of lunar satellite systems employed. The performance requirements reflect the current EOSS concept translated to the lunar orbit missions.

2. Internal communications - The earth orbital space station requirements for internal communications are functionally the same as those of the OLS. Similarly, the performance requirements are the same to the level of definition of the OLS effort.

3. Tracking - Tracking is integrated with the communication function, because all expected targets will be cooperative, and basic capability exists in the communications.

4. Ranging capabilities - This is based on assumption that the ranges and accuracies required for an OLS above the moon at 60 n mi will be similar to those for an EOSS at 260 n mi.

5. Flight management displays and controls - Management displays and controls have been organized to minimize necessary crew effort in normal operation with backup capability for critical areas.

6. Display and control types - The types and capabilities of displays and controls as listed are the result of EOSS tradeoffs involving essentially the same functional requirements. The selection criteria are based on the functional clarity in the preparation of information, logical application of controls, and flexibility required of the display and control functions.

7. Data processing capabilities - Peak experiment data rates, including both the OLS elements and lunar surface elements, combined with the normal systems load may exceed the acceptance rate of the soft data processor in the OLS at rare intervals. However, this should be avoidable by scheduling the use of temporary storage and/or direct relay of data to the MSFN. Normal volumes and rates are anticipated well within the stated values. Similar organization or processing to that of the EOSS is based both on similar requirements and on commonality of modules.

8. See Rationale (11) of Section 4.0.

7.5 GUIDANCE AND CONTROL SUBSYSTEM

The guidance and control subsystem (G&C) determines the actual and desired station state vector and provides the commands to the reaction control subsystem to maneuver the OLS to the desired state vector.

The G&C provides a stable attitude for the conduct of experiment operations. In addition, the G&C computes navigation and guidance commands for deployment, rendezvous and stationkeeping of free-flying experiments, manned and unmanned tug vehicles, and lunar landing vehicles.

The G&C subsystem also provides (in conjunction with the reaction control subsystem) damping of vehicle disturbances, control of attitude orientation, implementation of OLS maneuver requirements, and control of orbit makeup.

7.5.1 Functional Requirements

The functional requirements are arranged by the major mission phases.

Launch Through Orbit Insertion

The booster will provide guidance and control of the launch vehicle OLS prior to and including orbit insertion. The OLS G&C will be on standby.

Orbital Insertion Stage Separation

The OLS G&C shall be capable of stabilizing the OLS subsequent to orbit insertion stage (OIS) separation.

Premanning in Earth and Lunar Orbit

The G&C shall be capable of accepting a state vector update from the ground.

Initial Manning in Earth and Lunar Orbit

1. The ground complex shall provide OLS state vector and tracking data to the initial manning tug vehicle for use in effecting rendezvous with the OLS tug.
2. The G&C shall provide attitude hold for the OLS during fly-around inspection and during crew transfer.
3. The G&C shall be capable of automatic remotely initiated checkout prior to manning.

Initial Manned Operations

The G&C shall be capable of initial manning checkout utilizing only OLS onboard checkout facilities (no special checkout equipment) to the in-flight replaceable unit (IFRU).

Routine Manned Lunar Orbital Operations

1. The G&C shall be capable of providing OLS state vector and orientation data to the ISS.

2. The G&C shall be capable of automatically and selectively controlling the RCS thrusters.

3. The G&C shall compute the navigation and guidance commands for deployment, rendezvous, and stationkeeping of free-flying experiments.

4. The G&C shall provide navigation data to the ISS in support of tug operations (including retrograde delta V requirements and trajectory information to the lunar surface) and provide the capability for remote control.

5. The G&C shall maintain a stable OLS attitude in any of the following modes:

   Inertial attitude hold
   Earth referenced attitude hold (in earth orbit)
   Lunar referenced attitude hold (in lunar orbit)

6. The G&C shall be capable of performing energy management of station disturbances because of antenna positioning, crew and cargo movements, docking program elements, and CMG desaturation in conjunction with the ISS.

7. The G&C shall be capable of determining and controlling the required orbit makeup.

8. The G&C shall be capable of performing reorientation maneuvers as required for various OLS/docked vehicle configurations.

Logistic Support

The G&C shall be capable of holding the station attitude with respect to an inertial or local level reference during docking of tug and of recovering the OLS from the resulting docking transient.

7.5.2 Performance Requirements

The following tabulation defines the performance requirements for each functional characteristic identified in paragraph 7.5.1. Superscripts of the associated footnotes are indicated by the numbered item listed in Section 7.5.5.

Mission Phase	G&C Function	Performance Requirement
Orbit insertion	Monitor booster	None
Premanning	State vector Update for orbit position	GND supplied
Premanning	3-axis attitude hold[1]	+/- 5 degrees
Manning	State vector update for tug rendezvous	GND to tug (no station G&C Requirement)
Manning	3-axis attitude hold[2]	+/- 1.0 deg
	3-axis angular rates	+/- 0.05 deg/sec
	Unmanned checkout[3]	To assembly level
Initial manned operations	Initial manned checkout[4]	To IFRU level
Routine lunar operations	Altitude uncertainty[5,6]	+/- 330 ft 1 sigma
	In-track uncertainty	+/- 850 ft 1 sigma
	Cross-track uncertainty	+/- 490 ft 1 sigma
	Orbital velocity uncertainty	+/- 25 ft/sec RMS
Routine operations	Control of RCS thrusters	On-Off Signals to Valves and ignitor of any single engine or engine combo
Routine lunar operations	Computation of state vector[5]	Within 1 spherical n mi of desired location (3-sigma)
	Commands for free-flying experiment	

Mission Phase	G&C Function	Performance Requirement
	Docking range uncertainty[7]	
	1000 ft to 100 ft	+/- 1 ft 1 sigma
	100 ft to contact	+/- 0.5 ft 1 sigma
	Docking contact conditions	
	Position deviation (lateral)	+/- 0.5 ft allowed
	Velocity deviation (lateral)	+/- 0.3 fps allowed
	Velocity deviation (axial)	+/- 0.5 fps allowed
	Initial docking rate damped	90 seconds
	Recovery to original condition	160 seconds later
	Maximum docking transient acceleration	0.001 g acceleration
Routine lunar operations	Experiment operations OLS stability[5,6]	
	3-axis attitude hold (continuous)	+/- 0.25 deg
	3-axis attitude hold (30 minute duration)	+/- 0.10 deg
	3-axis attitude rate (continuous)	+/- 0.05 deg/sec
	3-axis attitude rate (30 minute duration)	+/- 0.01 deg/sec

Mission Phase	G&C Function	Performance Requirement
	Experiment operations acceleration[5]	
	Acceleration transients (up to 5 percent of time)	No more than 0.001 g
	Maximum acceleration (never to be exceeded)	No more than 0.01 g
Routine lunar operations	Orbit makeup altitude hold	+/- 0.1 n mi
Routine lunar operations	Reorientation rates (3-axis)	Up to +/- 0.25 deg/sec
Logistics support[8]	Docking range uncertainty[7]	
	1000 ft to 100 ft	+/- 1 ft 1 sigma
	100 ft to contact	+/- 0.5 ft 1 sigma
	Docking contact conditions	
	Position deviation (lateral)	+/- 0.5 ft allowed
	Velocity deviation (lateral)	+/- 0.3 fps allowed
	Velocity deviation (axial)	+/- 0.5 fps allowed
	Initial docking rate damped	90 seconds
	Recovery to original condition	160 seconds later
	Maximum docking transients recovery acceleration	0.001 g acceleration

7.5.3 Operability

See appropriate paragraphs in Sections 2.2 and 2.3.

7.5.4 Major Interfaces

Experiment Provisions

1. Attitude Requirements in Lunar Orbit.

   The OLS G&C shall be capable of maintaining station axes fixed with respect to inertial coordinates in X-POP inertial flight mode within ± 0.25 degree.

   The OLS G&C shall be capable of maintaining station axes within ± 0.25 degree in lunar referenced attitude hold with +Z axis at nadir in X-POP level mode on a continuous basis, except when it is in the inertial flight mode previously specified. For experiments, the station will fly with the -Y axis in the direction of the velocity vector.

   The station also shall be capable of operating in a fine pointing for periods up to 30 minutes, with vertical within ± 0.1 degree.

2. Stability Requirements in Lunar Orbit. The station G&C shall be capable of limiting angular rates about the vehicle axes to 0.05 degree/second continuously and to 0.01 degree/second in the fine pointing mode for periods up to 30 minutes.

3. Ephemeris Accuracy Requirements. Uncertainity in the knowledge of station orbit position and velocity shall be within the following limits:

Altitude	± 330 feet, 1 sigma
In-track	± 850 feet, 1 sigma
Cross-track	± 490 feet, 1 sigma
Orbit velocity	± 0.4% (25 fps), rms

4. Information Requirements. The G&C shall provide the following information to the ISS in support of the experiments:

   Current station attitude and rate and reference attitude alignment

   Position vector of targets-of-opportunity in lunar centered inertial coordinates

   Current station estimated state vector

Experiment to G&C reference calibration data

Guidance targeting and delta V commands for rendezvous, docking, deployment, and stationkeeping of free-flying subsatellites

Reaction Control Subsystem

The G&C shall provide on-off signals to the RCS solenoid valves and igniters. The input signals are required by each RCS engine.

Environmental Protection Subsystem

The environmental protection subsystem shall provide protection to externally mounted guidance and control subsystem sensors during prelaunch and launches phases.

Additionally, protection shall be provided for standby redundant external G&C sensors during all other phases. Such protection shall be designed to provide means for periodic inflight checks of standby devices.

Information Subsystem

1. The G&C system shall make the following information available to the ISS for use in displays, for system management, and in support of onboard checkout:

   Subsystem status measurements

   Power and mode status

   Attitude, attitude error, rate, and delta V information

   CMG gimbal angles and rates

   Docking range and angles and associated rates

2. The following represents the types of guidance and control computations that shall be performed within the ISS data processing assembly:

   CMG desaturation requirements (time-to saturation prediction)

   Current OLS attitude and rate and reference attitude alignment

   Position vector of targets of opportunity in LCI coordinates (tracked by astronaut using the G&C sextant-telescope)

Current OLS estimated state vector (position and velocity, orbital elements)

Lunar landing tug guidance parameters

Experiment to G&C reference calibration data

Guidance targeting and delta V commands for rendezvous, docking, deployment, and stationkeeping of free-flying vehicles.

Reaction jet commands and delta V prediction for OLS orbit maintenance

G&C configuration status (real-time)

G&C operation status (mode)

Real time failure identification and maintenance/replacement requirements

Energy management computations associated with jet firings

Control modelling, parameter estimate and adaption

Star tracker pointing commands

State vector propagation and update for free-flying subsatellites, and vehicles and stationkeeping and collision avoidance computations

3. The ISS shall make the following information available to the guidance and control in support of the previously mentioned computations:

Vehicle configuration

Sun and earth ephemerides

Star catalog

Range, range rate, OLS, and OLS rates from approach radars (for ranges greater than 1000 feet)

Scheduled initiation of station delta V's and CMG desaturation

Reaction jet attitude control inhibits and jet failure data

Crew interface - manual navigation sightings, operation mode commands, configuration commands, and maintenance-in-progress/accomplished data

Subroutines and bulk storage data loads

Permanent and temporary data storage

Experiment reference alignment

Maneuver schedule

Timing signal at 1 kHz rate

7.5.5 Rationale

1. Three axis local vertical attitude hold to within ± 5 degrees prior to manning is provided for communication antenna pointing, rendezvous reference acquisition, and to minimize the transient in acquiring more accurate attitude hold for fly-around inspection and manning. The 5 degrees are not critical, and in the event a long duration unmanned period becomes required, this function could be replaced by a free drift mode for the minimization of propellant use and control activity. The capability is provided for reacquiring local level attitude from an arbitrary attitude.

2. Transition to a ± 1 degree attitude hold in either a local vertical or inertial mode may be initiated by either the ground or an approaching vehicle. The values of rate stabilization to ± degrees/second and attitude hold to ± 1 degree are not critical and are chosen for convenience of the crew in effecting terminal phase rendezvous, fly-around inspection, unmanned checkout, docking, and manning.

3. Unmanned checkout is initiated by either ground command or by the manning vehicle and is performed to the assembly level or lower to allow the crew to determine subsystem operating capability and alternate modes prior to manning.

4. Initial manned checkout is performed to the IFRU level by the crew in conjunction with the ISS to allow for repair or replacement through the use of onboard spares.

5. These requirements are determined by experiment support provisions.

6. The OLS position uncertainty requirements are based on an experiment total pointing accuracy requirement of ± 0.25 degree, of which 0.16 degree is budgeted to position uncertainty. The total position accuracy is allocated as 0.133 degree in-track, 0.077 degree cross-track, and 0.026 degree altitude with a margin of 0.015 degree. For a 60-nautical mile lunar orbit, these accuracies can be met by the given position uncertainties. The velocity uncertainty represents 0.4 percent of orbital velocity and is required to meet tracking rate accuracy requirements to provide photographic resolution.

7. Docking errors are based on allowable contact conditions and the capability for manual backup. The number is based on demonstrated successful docking conditions and minimal interference with onboard experiments.

8. Guidance targeting for tug operations will be performed by the OLS G&C in conjunction with the ISS. These will include guidance targeting and delta V computation and mission planning for lunar landing. Manual backup control takeover capability also will be provided for unmanned and manned tug vehicles for rendezvous, docking deployment, and lunar landing.

7.6 REACTION CONTROL SUBSYSTEM

The reaction control subsystem (RCS) (together with the torques supplied by the G&C subsystem) provides the forces and moments necessary for attitude control of the OLS and those forces required for orbit altitude maintenance.

7.6.1 Functional Requirements

Launch Through Earth Orbit Insertion and Translunar Flight

The OLS RCS will be in a standby state during the launch and ascent to earth orbit phase and during translunar flight.*(1)

Premanning in Earth and Lunar Orbit

The OLS RCS shall be capable of providing control torques for stabilization during the premanning phase in conjunction with guidance and control commands.*(2)

*For rationale, refer to specified item number Section 7.6.5

Initial Manning in Earth and Lunar Orbit

The RCS shall be capable of providing control torques for station attitude hold during fly-around inspection and during crew transfer.*(2)

Initial Manned Operations

The RCS shall be capable of initial manning checkout utilizing only OLS onboard checkout facilities (no special checkout equipment).

Routine Manned Lunar Orbital Operations

1. The RCS shall be capable of providing control torques for reorienting the OLS to any of the flight modes required for routine operations.*(2)

2. The OLS reaction control subsystem (RCS) shall be capable of producing the necessary control torques for OLS stabilization and control for any configuration of OLS and docked elements.*(2)

3. The OLS RCS shall be capable of producing control torques for the OLS during docking of a space tug or other program elements.*(2)

4. The RCS shall be capable of providing forces for orbit maintenance requiring a delta V of 500 feet/second/year. *(6)

5. The RCS shall be capable of providing forces and control torques for desaturation of G&C control moment gyros.*(6)

6. The RCS shall be capable of providing the control torques and forces required for OLS attitude maneuvers.*(2)

Logistic Support

The RCS shall be capable of providing the control torques and forces required for holding the OLS inertially fixed during docking of a space tug and cargo module and of recovering the OLS from the resulting docking transient.*(2)

Cryogenic Storage Requirements

The RCS shall provide for storage of cryogenics and subsatellite propellants onboard the OLS or in docked modules.*(3)

*For rationael, refer to specified item number in Section 7.6.5

7.6.2 Performance Requirements*(3)

Design to Requirements. The RCS shall be designed and sized to normal operations for 180 days for a 90-degree inclination lunar polar orbit at 60-n mi altitude with an atmosphere as defined in NASA TM-X-53865. The design to flight mode is X-POP Y. The design representative and derivative configurations for the routine operation phase are given in Sections 2.0 and 7.0 of Volume V. *(4)

Operate to Requirements. The OLS shall be capable of operation at any degree of inclination in a 45 to 80-n mi lunar orbit. The OLS shall be capable of operating in both X-POP and Y-POP level inertial flight modes.*(4)

RCS Design and Sizing Requirements

Table 7-15 identifies the specific RCS design and size to requirements to satisfy the functions of paragraph 7.6.1.*(5)

Table 7-15. RCS Design and Sizing Requirements

Force Control Torque Function	Total Impulse (lb-sec, 180 D)	
	Representative OLS	Derivative OLS
Zero-g (180-day profile)		
Attitude hold	0.153×10^6	0.092×10^6
Attitude maneuvers	0.012×10^6	0.012×10^6
Maintain orbit	2.049×10^6	2.559×10^6
Emergency	0.082×10^6	0.081×10^6

Cryogenic Storage Requirements*(5)

See Table 7-16.

*For rationale, refer to specified item number in Section 7.6.5

Table 7-16. Cryogenic Storage Requirements
(including subsatellite propellant)

Configuration	O_2	H_2	N_2	N_2H_4
Representative	6823	1645	3551	7811
Derivative	8042	1913	7349	7811
For derivation of the above requirements see the reaction control subsystem section of Volume V.				

7.6.3 Operability

See the appropriate paragraphs in Section 2.2 and 2.3.

7.6.4 Major Interfaces

The RCS interfaces with other subsystems are identified in Figure 7-1. and described in the following paragraphs.

Experiments

RCS shall provide 455 lbm N_2 and 7811 lbm N_2H_4 propellant storage for 180 days for the experiment provisions.

Structures

The liquid oxygen, liquid hydrogen, liquid nitrogen and hydrazine tanks shall be located in unpressurized areas within the environmental shield of the OLS in redundant locations for reliability.*(7)

Environmental Protection Subsystem

The environmental protection subsystem must protect the RCS cryogenic tanks from penetration by micrometeoroids. The heat leaks to the cryogenic tanks shall be controlled to boil off an amount appropriate to the usage demands.*(7)

Electrical Power Subsystem

Electrical power shall be supplied on a demand basis to each valve, electric blower, and ignitor circuit. If fuel cells are used in the OLS, the RCS shall provide storage of 3697 pounds of oxygen and 533 pounds of hydrogen reactants based on 180-day storage.*(8)

*For rationale, refer to specified item number in Section 7.6.5

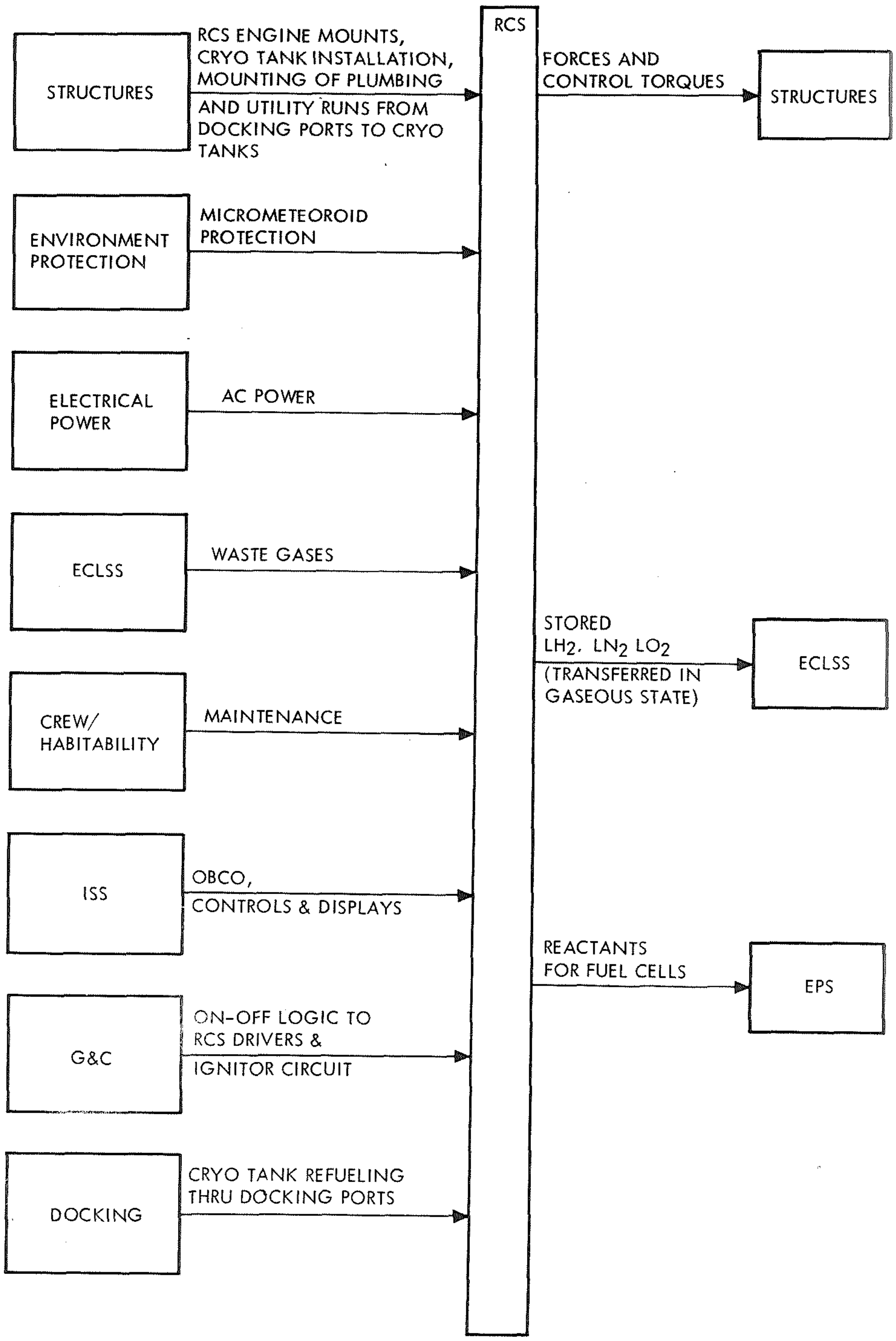

Figure 7-1. RCS Interfaces

Environmental Control and Life Support Subsystem

The RCS shall supply storage of subcritical N_2, O_2, and H_2 sized to the following for ECLSS:

ECLSS Function	Representative OLS	Derivative OLS
Leakage	O_2 - 1247 lbm	O_2 - 2394 lbm
	N_2 - 3096 lbm	N_2 - 6894 lbm
Repressurization (20K ft^3)	O_2 - 350 lbm	O_2 - 350 lbm
	N_2 - 1150 lbm	N_2 - 1150 lbm
Sabatier unit	H_2 - 324 lbm	H_2 - 324 lbm

The above requirements are based on 180 days storage capacity.*(9) For a detailed development of these requirements see the reaction control subsystem section of Volume V.

Information Subsystem

Status data shall be provided for all of the propellant valves, engines, and propellant fans to determine their open-closed or on-off conditions. Selected propellant tank, propellant line, propellant accumulator, and engine package temperature and pressure data will be available to the ISS to facilitate the control and monitoring of the RCS. The information subsystem shall provide control commands and checkout commands based on the data provided by the RCS. The ISS alarm system shall advise the astronauts of any RCS anomaly. The information subsystem shall also keep an inventory of inflight replaceable units. During a resupply mode, the information subsystem shall provide command signals to the cargo module to control the propellant resupply flow. The ISS shall provide a manual control capability for the RCS jets that overrides the automatic commands.

The interface between the ISS and the RCS shall be at the remote acquisition and control units (RACU). The RACU may be contained within an inflight replaceable unit of the RCS subsystem.

The ISS shall provide commands to the RCS. All commands shall be low-level digital logic pulses.

*For rationale, refer to specified item number in Section 7.6.5

Guidance and Control Subsystem

The guidance and control subsystem supplies on-off control signals to the reaction control subsystem solenoid valves and igniters. These input signals are required by each engine of the RCS.

Docking Provisions

The capability to refuel the cryogenic tanks via any normal docking port, shall be provided. Refueling of the cryogenic tanks from a cargo module shall be possible regardless of whether or not the station is pressurized. The following capabilities shall be provided across the docking interface:

Transfer of liquid oxygen
Transfer of liquid hydrogen
Transfer of liquid nitrogen

A minimum of one fill and one vent connection for each fluid shall be provided.

7.6.5 Rationale

1. All propulsion functions are handled by the orbit insertion vehicle during these phases.

2. The OLS RCS must be capable of stabilizing the vehicle to permit initial docking, subsequent docking, orbital operations, experiment performance, and crew and cargo transfer. These operations require a stable platform. The OLS RCS also must be capable of reorienting the vehicle to facilitate special experiments and observations.

3. The space tugs and the lunar excursion vehicles will require large amounts of cryogenic oxygen and hydrogen. Because these materials must be stored with the station, it would be practical to have the RCS use this supply also. Also, it is practical to assign all of the cryogenic storage to the RCS for centralized accountability.

4. The RCS shall be designed to support the projected OLS mission.

5. The OLS RCS must be sized to perform the required operations and to respond to the control commands. The specific requirements are developed in the reaction control subsystem section of Volume V.

6. Orbit deterioration can only be countered through the application of a thrust force. The thrust levels required are within the capabilities of an RCS. Also, normal orbital attitude maintenance will periodically saturate the control moment gyros. A steady firing of the proper RCS engine will turn the gyros back to their starting positions.

7. The cryogenic tanks must be located in a vacuum environment to eliminate convective and reduce conductive heat leak into the tanks. At the same time, the tanks must be shielded from the sun to prevent radiative heating. To ensure long usage life, the tanks must be protected from meteoroid damage. Location of the tanks outside of the pressure hull considerably reduces the possibility of cryogenic fluid spilling inside of the living areas.

8. Electrical power is required to control the RCS. Any fuel cell used on the OLS logically would use oxygen and hydrogen from the RCS. These cryogens must be vaporized for use in the RCS as well as for use in the fuel cells. The use of a common supply simplifies the design and accountability requirements.

9. A very large requirement for nitrogen storage is anticipated for the OLS. To keep the volume down, it is reasonable to store this nitrogen as a cryogenic liquid. This liquid nitrogen would then be stored with the other cryogenic liquids and assigned to the RCS to consolidate accountability. If liquid nitrogen were not used, liquid ammonia or hydrazine, plus high pressure nitrogen gas, may be required in additional storage areas.

7.7 ENVIRONMENTAL PROTECTION SUBSYSTEM

The environmental protection subsystem (ENPS) provides (1) temperature and heat control for structure, subsystems, integral experiments, assemblies, and components by passive thermal design techniques independent of vehicle attitude in orbit, (2) shielding to break up and/or deflect and/or absorb micrometeoroids that may otherwise endanger the OLS, (3) protection for the crew and sensitive equipment from radiation present in the natural environment, and (4) protection against aerothermodynamic deterimental effects during boost.

7.7.1 Functional Requirements

Thermal Protection

1. The ENPS shall provide, in conjunction with the ECLSS, a general limitation on the minimum temperature that the interior walls of the pressurized volumes of the OLS will experience.*(1)

2. The ENPS shall provide the following:

   A limitation on the maximum heat load gain internally to the OLS from the external environment.*(2)

*For rationale, refer to specified item number in Section 7.7.5

A limitation on the maximum heat load loss from the OLS to the external environment.*(2)

Insulation to limit the interior wall temperature of unpressurized OLS volumes.*(3)

Thermal independence to vehicle orbital attitude in conjunction with the ECLSS.*(4)

3. ENPS shall preclude condensate formation on inner pressure wall surfaces.*(5)

Micrometeoroid Protection

1. ENPS shall limit the possibility of a micrometeoroid penetrating the crew or systems compartments.*(6)
2. ENPS shall prevent catastrophic failure of fluid storage tanks due to micrometeoroid penetration.*(6)
3. ENPS shall prevent failure of external radiators caused by micrometeoroid penetration.*(6)

Radiation Protection

ENPS shall limit, to allowable levels, the total radiation exposure dosage to OLS crew members.*(6)

Aerothermodynamic Protection

1. ENPS shall protect the OLS during boost from aerothermodynamic effects (heating and pressure) that can impair mission performance.*(7)
2. Boost-protective devices that impair mission performance shall be discarded prior to earth orbit insertion.*(6)

7.7.2 Performance Requirements

Thermal Protection

1. The minimum interior wall and equipment surface temperatures shall be limited to 57 F.*(8)

   Note: ECLSS shall provide a radiant heat sink of 65 F minimum in the OLS interior.

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*For rationale, refer to specified item number in Section 7.7.5

2. The representative OLS heat rejection requirements are given in Table 7-17.

Table 7-17. Heat Rejection Requirements*(2)

	Light Side (Solar Cell)		Dark Side (Fuel Cell)	
	Core	Boom	Core	Boom
Subsystems	24.0 kw	0 kw	21.0 kw	0 kw
EPS Efficiency				
Distribution	1.5	4.5	1.3	4.0
Fuel cell	0	0	0	17.5
Electrolysis	0	1.3	0	0
Metabolic	1.1	0	1.1	0
Total	26.6 kw	5.8 kw	23.4 kw	21.5 kw
	(90,000 Btu/hr)	(19,800 Btu/hr)	(80,000 Btu/hr)	(73,500 Btu/hr)

3. The external environmental heat loads to the internal volume are assumed to be zero for the purposes of thermal protection evaluation because their actual magnitude is small by comparison to OLS generated loads.

4. The interior walls of unpressurized areas of the OLS shall be maintained at the pressure wall temperature.*(3)

5. The heat loads on the modules of the derivative OLS configuration are given in Table 7-18.

Micrometeoroid Protection

1. Protection to a probability of 0.9 of no micrometeoroid penetration of crew or systems compartment for 10 years shall be provided.*(9)

2. Pressurized storage vessels shall be protected from failure caused by micrometeoroid impact.*(9)

*For rationale, refer to the specified item number in Section 7.7.5

Table 7-18. Derivative OLS Module Heat Loads

Module	Heat Load (kw)
Cargo Module	0.4
Core 1A	4.8
Core 1B	4.3
Control Center Module 1	4.3
Control Center Module 2	4.3
Galley Module	8.0
Crew Quarters Module 1	7.2
Crew Quarters Module 2	7.2
Power Module	6.6

Radiation Protection

1. The crew radiation dose shall be limited to the following: *(9)

All Doses in rem

Depth/Period	Career	Year	30 Days
Skin (0.1 mm)	2400	240	150
Eye (3 mm)	1200	120	75
Marrow (5 cm)	400	40*	25

Note: *This limit may be doubled if the crewman is not exposed to any further radiation for the succeeding 12 months following the one-year counted for exposure (i.e., no more than 80 rem in a 24-month period).

2. The ENPS shall provide for a solar storm shelter with the required shielding to limit the crew radiation dose to the above levels.*(12)

Aerothermodynamic Protection

1. Aerodynamic heating limitations and aerodynamic pressure limitations are a function of launch vehicle configuration, launch trajectory, and launch vehicle characteristics.*(7)

2. Boost protective cover shall be jettisoned. Disposal shall be such that after ejection there shall be no recontact with the station or launch vehicle.*(6)

*For rationale, refer to specified item number in Section 7.7.5

7.7.3 Operability

Reliability

See Section 2.2.

Maintainability

The capability of replacing damaged meteoroid bumper panels shall be provided.*(6)

Useful Life

See Section 2.2.

Environment

See Section 2.2.

Human Performance

See Section 2.2.

Safety

See Section 2.3.

7.7.4 Major Interfaces

Experiment Provisions

Environmental protection shall be provided for integral experiments as part of the normal protection for the OLS. Radiation protection shall be provided for stored experiment film to the extent required. Environmental protection of in-use equipment and subsatellites shall be provided by the experiment.

Structures

The structure shall provide for the solar storm shelter required to meet the radiation dose limits specified above.

Electrical Power Subsystem

The EPS must provide the environmental protection subsystem with 335 watts overall mission average electrical power.*(11)

*For rationale, refer to specified item number in Section 7.7.5

Environmental Control/Life Support Subsystem

1. ECLSS shall maintain a mean internal radiant temperature of 70 F nominal, 65 F minimum, and 75 F maximum.* (2)

2. The station atmosphere dew point temperature shall not exceed 57 F maximum. No condensation shall be allowed to form on internal surfaces.*(8)

Information Subsystem

1. The environmental protection subsystem shall provide the following quantities and types of measurements to the ISS:

Type	Quantity
Operational	200
Additional fault isolation	210
Total analog	410

The ISS shall provide commands to the environmental protection subsystem. All commands shall be low-level digital logic pulses.

2. The solar storm shelter shall incorporate the backup control center consoles to permit the crew to maintain the minimum required station operations during a major solar flare event.

Reaction Control Subsystem

The environmental protection subsystem must protect the RCS cryogenic tanks from penetration by micrometeoroids. The heat leak to the cryogenic tanks shall be controlled to boil off an amount appropriate to the usage demands.

Guidance and Control Subsystem

The environmental protection subsystem shall provide protection to externally mounted guidance and control subsystem sensors during prelaunch and launches phases.

Additionally, protection shall be provided for standby redundant external G&C sensors during all other phases. Such protection shall be designed to provide means for periodic inflight checks of standby devices.

*For rationale, refer to specified item number in Section 7.7.5

Docking Provisions

At each docking port, the docking function shall provide the attachment points so that the environmental protection subsystem can provide a docking port cover. This cover is required to protect the docking port against aerodynamic and boost loads during launch and to provide on-orbit protection from micrometeoroids when the docking port is not in use. Provisions shall be made for OLS remote opening of the protective cover at two docking ports for the initial docking operation.

Crew Habitability

1. Provide thermal and meteoroid protection.

2. Provide radiation protection.

Radiation protection shall be provided to limit crew radiation dosage as specified below (all doses in rem).

Depth/Period	Career	Year	30 Days
Skin (0.1 mm)	2400	240	150
Eye (3 mm)	1200	120	75
Marrow (5 cm)	400	40*	25

*This limit may be doubled if the crewman is not exposed to any further radiation for the succeeding 12 months following the one year counted for exposure (e.g., no more than 80 rem in a 24-month period).

The rate limit for radiation from all artificial sources shall not exceed 0.15 rem/day.

7.7.5 Rationale

1. This is required to maintain acceptable environment, precluding condensation on walls, to ensure operability and reliability.

2. These requirements essentially establish the major interfaces between ECLSS and thermal protection and usually provide the major driver to the passive thermal/structural design (e.g., insulation, thermal conductance control of structure, coatings, etc.).

3. Unpressurized volumes are used for storage. Wall temperatures are stabilized to requirements of the stores.

4. From the Guidelines and Constraints document; imposed to eliminate thermal interferences in mission planning or objective.

5. From the Guidelines and Constraints document; presence of moisture promotes bacteria growth and could freeze on depressurization and jam mechanisms.

6. This requirement is necessary for crew safety considerations and to ensure operability and reliability.

7. It is necessary to maintain complete structural integrity during boost to ensure crew safety and OLS operability during subsequent manned mission phases.

8. The Guidelines and Constraints document sets the maximum air moisture content at 12 mm Hg of water partial pressure. This establishes the dew point temperature at 57 F.

9. From the Guidelines and Constraints document; it is necessary to ensure safety and operability.

10. Fault isolation, repair, maintenance, checkout, monitoring, etc., will be performed on data supplied by electrically powered instrumentation.

11. Provides boundary temperatures upon which to base the passive thermal/structural design. Power requirement from Electrical Load Analysis of Section 7.3.

12. Due to the nature of the radiation environment in lunar orbit, a storm shelter must be provided in which the crew can take refuge during major solar flare events. For further discussion, see the Radiation Protection section of Volume IV.